BBC

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Space suits that will keep us alive on the Red Planet

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FOCUS

SCIENCE AND TECHNOLOGY

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Mark of mankind
What will remain when we've gone?

Genetic records
Storing books in DNA

Shhh!
Inside the quietest room in the world

SPECIAL REPORT

THE SEARCH FOR EARTH'S TWIN

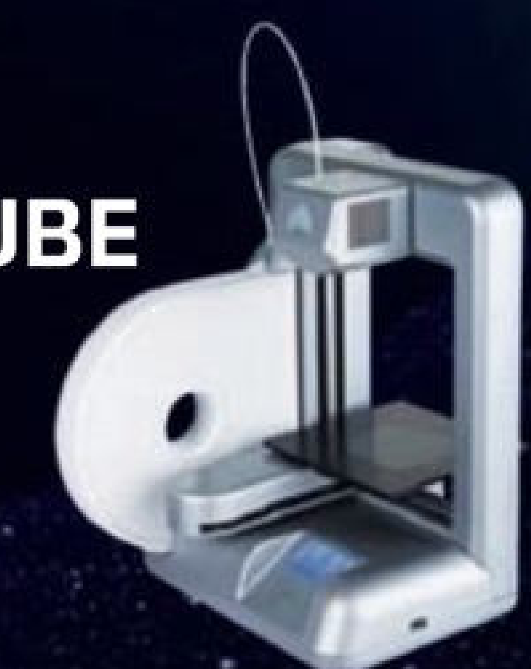
How we'll find another world just like ours

BIOBOT REVOLUTION
ROBOTS THAT MIMIC ANIMALS ...AND HUMANS

SIR DAVID ATTENBOROUGH
ON WILDLIFE TV'S NEXT BIG THING

HOW DO WE KNOW?
Our new series on the key discoveries: this month the atom's anatomy

ON TEST: CUBE 3D PRINTER
What it does and why you'll want one



Q&A
- Why do we have earlobes?
- Do stars spin?
- Why does a sneeze feel nice?

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WELCOME TO FOCUS

RECALLING THE VIEW from the surface of the Moon, the late Neil Armstrong said: "It suddenly struck me that that tiny pea, pretty and blue, was the Earth." That was in 1969, but pretty soon we should get a similar glimpse of a different planet, through the lens of the world's most powerful telescope. Building work on the Extremely Large Telescope begins this year and, as we reveal on page 34, it will tell us how rare – or otherwise – our planet really is.

As for the Earth, will our activities today leave a trace in the rocks in the far future? Turn to page 53 to find the answer – it's not as obvious as you'd think. We also catch up with BBC presenter Dallas Campbell, whose BBC One series *Generation Earth* showcases the huge changes to cities, transport and agriculture in recent decades.

Talking of change, *Focus* itself has evolved. As well as a striking design, we've introduced some brand new sections. To Do List is your monthly listings guide to science TV and radio, events, books, apps and games. Tech Hub gives you the lowdown on game-changing gadgets, present and future – this month it's the world's first consumer 3D printer. And How Do We Know? brings you up to speed on a different area of science every month – find out about the atom in this edition.

There's much more to explore – just dive in.

Graham

Graham Southorn, Editor

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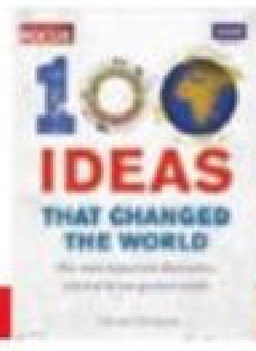

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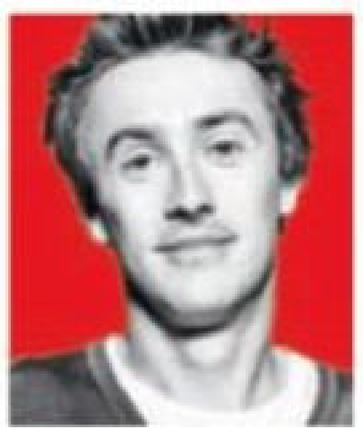
APPEARING IN THIS ISSUE...

Sir David Attenborough

Soon to be celebrating his incredible career with the BBC programme *60 Years In The Wild*, on p68 the legendary broadcaster tells us how science has changed the art of wildlife filmmaking over the years.

Stephen Baxter

The acclaimed British science fiction writer is the author of *The Science Of Avatar* and, with Terry Pratchett, *The Long Earth*. In his new column on p122, he ponders the prospect of drilling for minerals on other planets.



Dallas Campbell

A familiar face to TV viewers from *Bang Goes The Theory*, Dallas returns to our screens in the flagship BBC One series *Generation Earth*, in which he shows us how we have changed the planet during our brief time here – find out more on p56.

Dr Sue Bowler

Sue is editor of the journal *Astronomy & Geophysics* and teaches at the University of Leeds. Trained as a geologist, she's interested in life on planets – including Earth. On p53, she looks at what mankind will leave behind.

WANT TO SUBSCRIBE? Just fill in the form on p32 and you'll get the magazine delivered each month – and save 50 per cent of the cover price!

EXISTING SUBSCRIBERS Turn to p32 for an exclusive interview with palaeozoologist **Darren Naish**

COVER INSET: CORBIS

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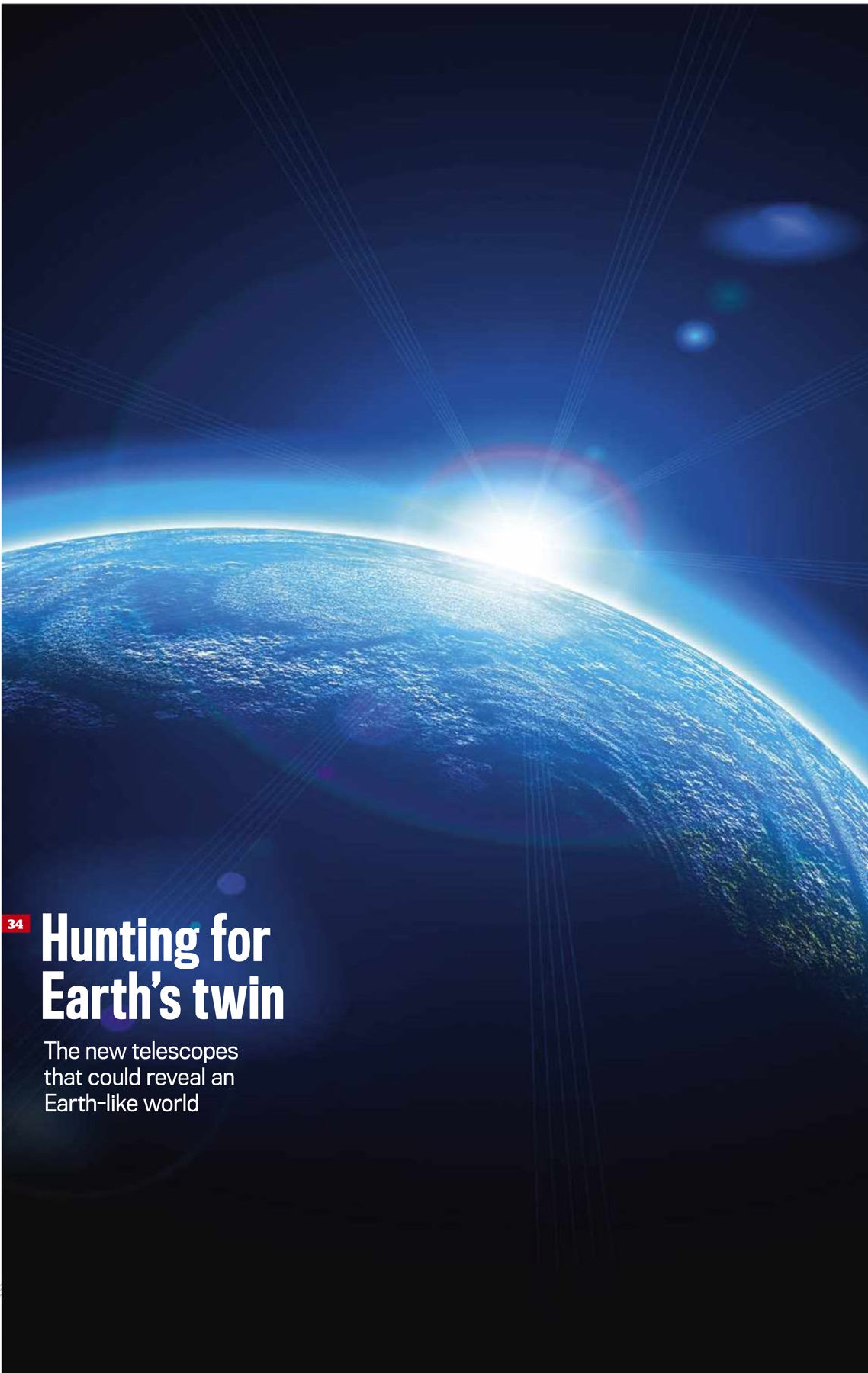

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Hunting for Earth's twin

The new telescopes that could reveal an Earth-like world

PHOTO: THINKSTOCK, JAMES CHEADLE, SUPERSTOCK, ADAM GASSON, KATJA ZANELLA-KUX/OEWF, STUDIO4PHOTO.CO.UK

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Awe-inspiring images from the world of science

MegaPixel

Techno trees

STANDING UP TO 50m tall, these man-made 'supertrees' are the centrepiece of Singapore's 'Gardens by the Bay', a £500m project that aims to transform the city into the botanical capital of the world. "The main driver was to show off plants on a scale that had not been seen before," says Andrew Grant of Grant Associates, the British landscape architects that designed the project.

The trunks of the 18 supertrees – reinforced concrete tubes enclosed in a steel mesh – are vertical gardens covered in over 200 species of *epiphytes* – 'air plants' such as bromeliads that grow without soil. The plants naturally draw moisture from the humid atmosphere of tropical rainforests but, in the drier conditions of southeast Asia, water is supplied by an irrigation system on the trunks of the artificial trees.

The man-made trees are also a model of sustainable technology: at night, they're illuminated by LEDs powered using solar energy from the day, captured by photovoltaic panels on the funnels of the branching metal canopies. Visitors can experience panoramic views of Singapore's bay and skyscrapers by taking a lift up to a bistro in the largest tree, or stroll along an aerial walkway that connects two 42m-tall supertrees.

PHOTO: GETTY

MegaPixel

Eat like a horse

THIS TINY DENISE'S pygmy seahorse (*Hippocampus denise*) is no bigger than a 2p coin. Its pectoral fins are so small that it struggles with locomotion, though it can manage to rotate and change direction. As a result of these physical shortcomings, it spends most of its life clinging to the branches of sea fans rather than swimming around, which is why it has evolved such specialised camouflage.

The seahorse is thought to feed from its perch by sucking in passing plankton. "Research hasn't been done to discover exactly what this specific species eats yet," says Dr Lucy Woodall, a conservation geneticist based at the Natural History Museum who specialises in seahorses. "But this feeding tactic requires a lot of energy, so seahorses actually have to be quite voracious carnivores to survive."

PHOTO: ALEX MUSTARD/NATURE PL

MegaPixel

Taking aim

FROM THE WALLS of this spherical chamber, 176 lasers will fire at a target with the aim of creating sustainable nuclear fusion. That will be the goal of the Laser Megajoule Project (LMP), based near Bordeaux in France, when it's turned on in 2014.

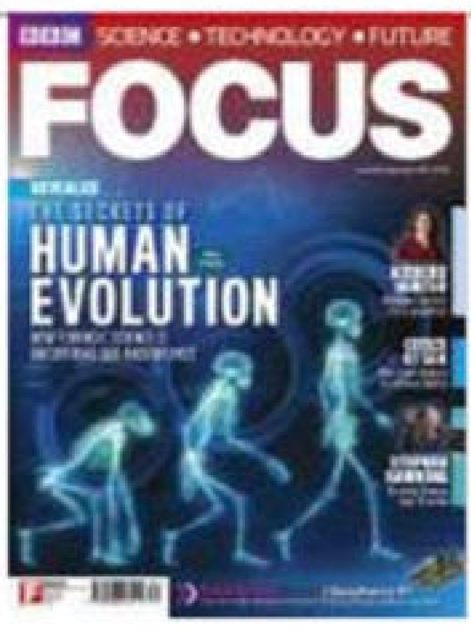
The lasers, aimed at deuterium molecules held in the centre, will create astronomical amounts of pressure. This will force the atomic nuclei in the target to fuse together, releasing energy as they do. With enough heat and pressure, it's hoped that the reaction will reach ignition – the point at which it becomes self-sustaining, creating more energy than is put in. It's the same process that powers our Sun and could solve the world's energy needs.

"Our goal is to reach temperatures of up to 10 million degrees Celsius" says François Geleznikoff, director of the Nuclear Weapon Department at the LMP. "Up to that point we will be running dozens of experiments to better understand the behaviour of nuclear particles."

PHOTO: MATHIAS SGANDURA/CEA

REPLY

Your opinions on science, technology and our last issue



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Letters may be edited for publication

Colin Farrell moulds his memory in the film *Total Recall*

Masters of memory

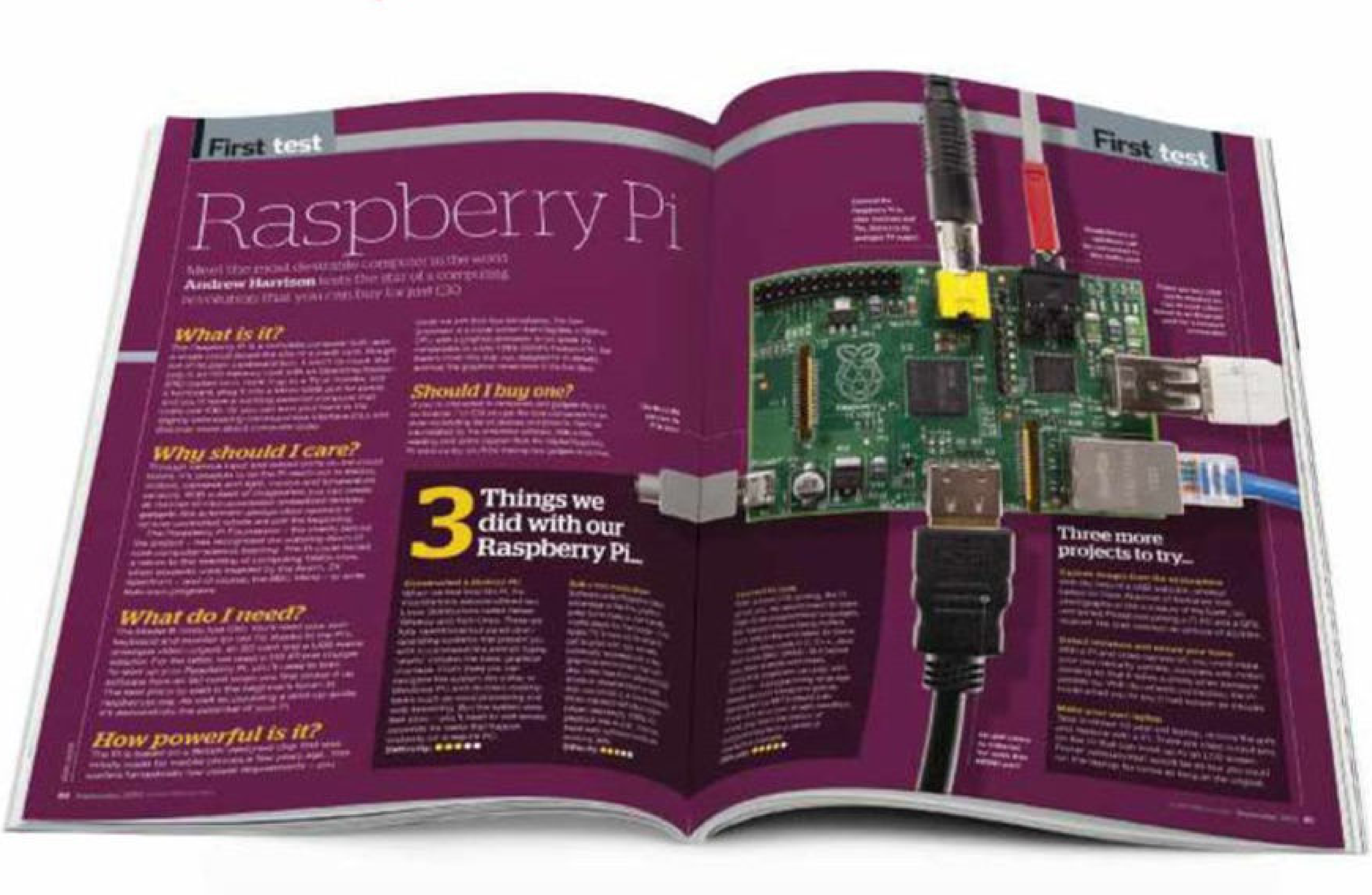
Thanks to 'The Masters Of Memory' article (September, p55) I finally understand Facebook. Those 'Friends' who post their status as: 'Just enjoying a nice cup of coffee' with an accompanying photo of said beverage are not, as I have long believed, wasting my time with egocentric, dull trivia. They are in fact 'lifelogging' in order to assist their unreliable memory recall in the future. I have duly updated my Facebook status to: 'Eureka!' with a photo of *Focus* magazine and a foaming cup of cappuccino in case I forget this momentous breakthrough.

Bryan Moiser, Hull

Nobody home

Stephen Baxter's article in the August issue (p26) got me thinking. He mentions that "future missions may take longer [than previous ones]. An interstellar probe might take a century to reach Alpha Centauri". I have been intrigued for some time with space travel but have never found any calculations published concerning how long it would take to reach other stars. Experts generally only quote that a quantum change is necessary to the speed of spacecraft before any attempt is made to travel outside our Solar System, so I thought I would do some simple calculations myself. I started with a Google search for the fastest spacecraft speed recorded and found that it was 252,000km/h.

MESSAGE OF THE MONTH



The Raspberry Pi was put through its paces in the September issue

The Pi's the limit

I would urge every parent to buy their children a Raspberry Pi, as reviewed in issue 246 (p88). Get the kids started, and they'll make amazing progress.

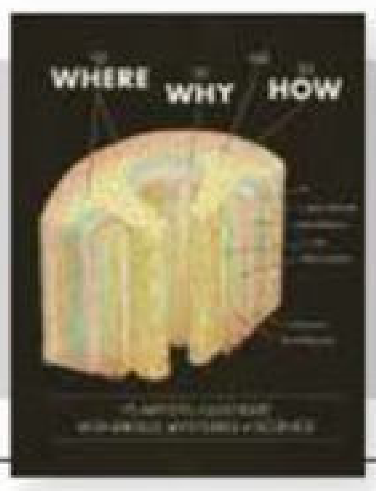
My son works as a website developer, but it is shameful to relate that school IT lessons did nothing to prepare him for such work. With a background in IT, I was able to help him grasp writing simple programs in BASIC, and he went on to teach himself much of the rest. Left to the school curriculum, he would have entered the work environment barely able to type a letter or produce a simple spreadsheet. Our kids deserve better, and the Raspberry Pi might just be the tinder to light the fires of their imagination.

Parents needn't worry about not having the computing skills to help their children – get them a Raspberry Pi at a young age and their natural inquisitiveness will guide them. Your review article would make a great starting point. Britain's IT future suddenly looks a lot brighter.

Alan Thomas, Shepperton

The school IT curriculum has indeed changed over the years, gradually eschewing computer programming in favour of teaching graphical user interfaces and popular applications. For more on these issues, and planned changes to the school curriculum, listen to an episode of BBC Radio 4's Material World *from January 2012 at http://bbc.in/NCNXEf*

Write in and win!



Alan Thomas wins a copy of *The Where, The Why And The How* (Chronicle Books, £15.99). Send us your views to win next month's prize.

PHOTO: SONY PICTURES/PICSELECT.COM, GLUEKIT

If this could be improved a little, say to 300,00km/h, and maintained throughout interstellar travel, it would take 3,600 times longer that light. With Alpha Centauri being approximately 4.2 light-years away, it would therefore take about 15,120 years to reach this nearest star. Imagine the disappointment when, after all this time and over 600 generations of human beings later, they find no life-supporting planet available.
Stuart Moyle, Aberdeen

Hopefully we'll know a lot about our destination before we set off. For some exoplanets, astronomers have already been able to measure the temperature of their atmospheres and detect gases like methane and water vapour. – Ed

YOUR COMMENTS ON FACEBOOK

On facebook.com/sciencefocus we asked:
Should the Curiosity rover be followed by a manned mission to Mars? You replied...

Callum Sweeney Send me! I'll just sleep most of the 8-month trip. Couple of books and my PS Vita. Won't be that bad :)

Richard Peter Becton To paraphrase Ogilvy, the astronomer from *War Of The Worlds*, "The chances of anything going to Mars, are a million to one."

Trevor Hawkins What could a human do more than a robot? But it would be truly amazing to say that a human has visited Mars.

Gillan Alexander Landing a rover on Mars the ambitious way shows what can be done but to get the human race interested in space travel again, man has to go to Mars.

Sara Harvey We need a good old fashioned Space Race (just without the hostilities). C'mon China or whoever and hurry up!

Toby Lerone Defo Why not? It doesn't matter 'bout cost, this will be the first of many missions that will eventually lead humans to travel anywhere in the Universe!

Dave Rolfe It needs to be something more than flags and rocks. It should be a long-term mission to set up a manned science station. We've done it with ISS!

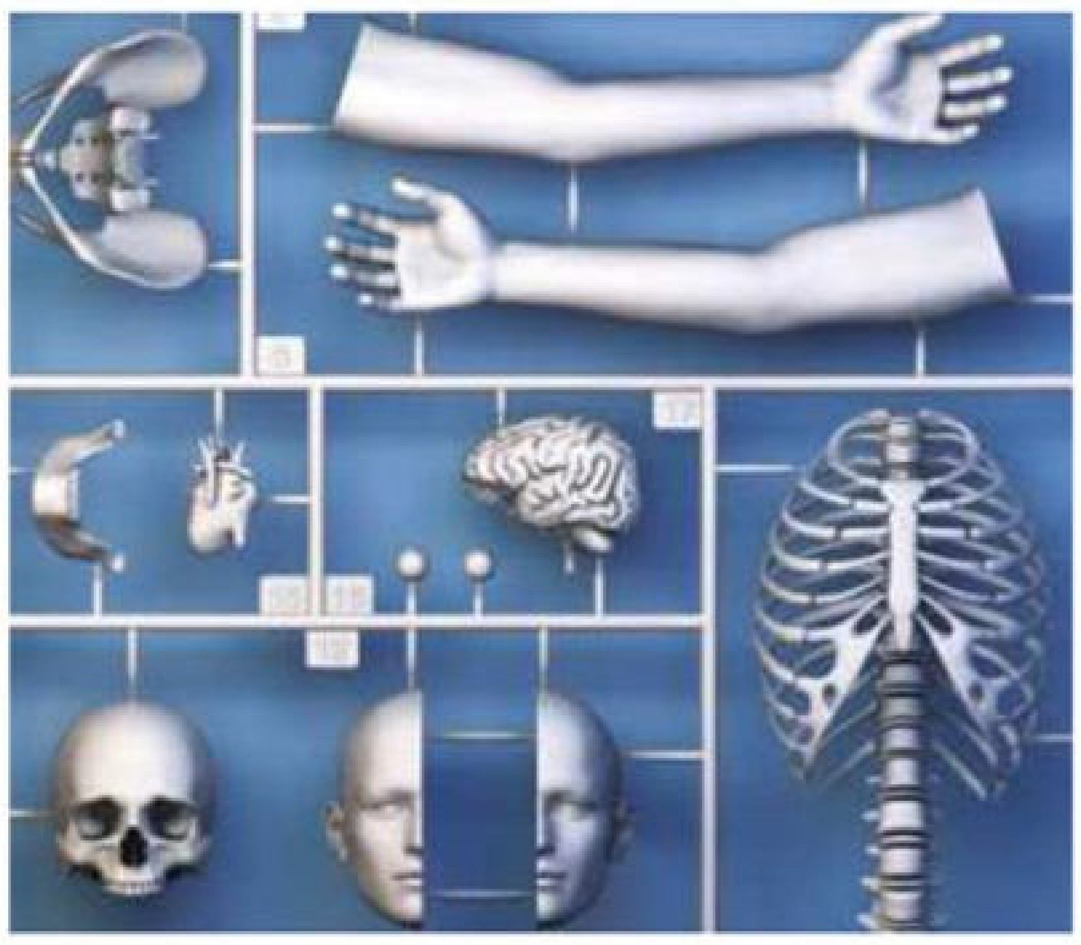
Cameron Martin Send robots, just in case. Human life is too precious to waste.

Tree-mendous

In August's Q&A, the Question of the Month (p74), 'How many trees are needed to provide enough oxygen for one person?' was answered by Luis Villazon. Hats off for providing such a clear and succinct response. I am going out immediately to plant eight trees!
Richard O'Neill, Glasgow

Body of evidence

I've only recently subscribed to *Focus* magazine, and in that short space of time I've learnt loads. I've just finished 'Grow your own body' (August issue, p64). What an amazing read that was; it gave me tingles all down my spine thinking about what humans can do with the technology we have.
Steve Allen, Portsmouth



Replacement body parts could be just around the corner

In defence of dogs

Mr Roger Webber says that dogs are the most infectious animal to humans (issue 244, p28). I am sorry to disagree, but that honour goes to humans by a factor of about 10 to 1. In fact, dogs were used to take fleas from humans by the fact that their higher body temperature attracted them, which is where the term 'lap dogs' comes from. You are far safer in the company of dogs than humans. This is no surprise as, by definition, anything that a human can catch from a human can be passed to a human, but the same is not true in either direction: dog to human, human to dog.
David J Beck, Hinckley

Oops!

In the feature 'One Giant Leap' (issue 244, p35), we state that the Red Bull Stratos capsule is 6m in diameter. It is in fact 6ft in diameter.

FOCUS
SCIENCE AND TECHNOLOGY

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News and views from the world of science

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The interface that lets you 'feel' objects on a tablet screen

MAN-MADE CLIMATE FIX
Should we create artificial clouds to cool the climate?

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MARTIAN MICROBES
The hardy bacteria being developed to live on Mars

p24

THE BIG STORY

Entire book encoded in DNA

Forget solid-state drives and holographic discs, the future of data storage is genetic material ➔

The book of life: DNA has been used to encode 53,000 words and 11 images

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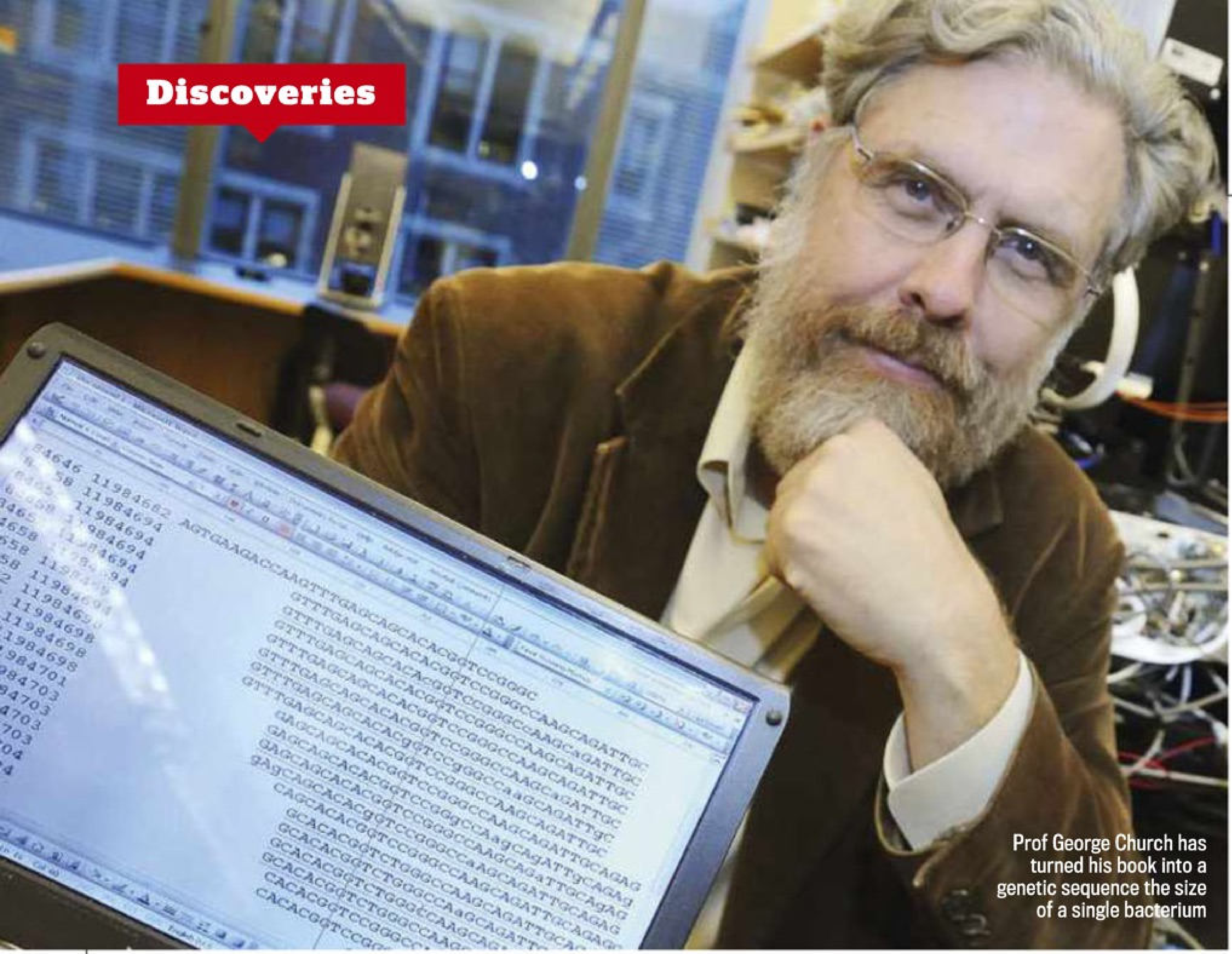


Prof George Church has turned his book into a genetic sequence the size of a single bacterium

IT'S OFTEN CALLED the 'book of life' and now DNA has been used to store the contents of an actual book. The 53,000 words and 11 images of an entire work of non-fiction have been translated into life's language. This is 1,000 times the amount of data previously encoded in genetic material – a development that marks the dawn of a revolution in how we store information.

Already, 70 billion copies of the book have been 'printed' in DNA by geneticists in the US, yet it all fits into a droplet of liquid. It's the incredible density of genetic material as a storage medium that's one of its big advantages – that, along with its robustness.

"DNA can be stored in very suboptimal conditions, in dead animals for example, and it's lasted for 400,000 years. We can read off the genes just fine," says Professor George Church at Harvard Medical School, who led the research. "It lasts far longer than a Blu-ray."

It's Church's new book, *Regenesis: How Synthetic Biology Will Reinvent Nature And Ourselves* that has been encoded. His team used a webpage version as their raw material, in which all the words and images are stored in a series of 1s and 0s. The chemicals, or 'bases', whose sequence makes up our genetic code, were then used to represent the 1s and 0s, with A or C representing 0 and G or T a 1.

All these bases were printed onto a DNA micro-array, a piece of equipment that resembles a microscope slide, using a specialised inkjet printer. This DNA sequence – the book's 'genetic code' – was then stripped off and stored in liquid. The book would be just under 300 pages in printed form, while its genetic code is about the size of a bacterium's. Current cutting-edge storage technology, such as solid-state memory, is "thousands and thousands of times less dense than DNA," Church says. Another advantage is that other experimental digital storage media, such as quantum holography, require very cold temperatures and tremendous amounts of energy.

It is the huge strides in the speeds of DNA synthesis and sequencing – the speed with which genetic material can be created and read – that have paved the way for this advance. In spite of recent developments in sequencing, if the genetic code were to be converted back into a book it would take 10 days, so genetic storage is more likely to be used to archive data than appear inside a PC.

ANDY RIDGWAY

ANALYSIS

Drew Endy

Assistant Professor in the bioengineering department at Stanford University in the US

Until Prof George Church achieved his book-to-DNA feat, biologist Craig Venter held the gene-coding record, having recorded a simple message in an artificial bacterium's genetic material (see 'Timeline' below).

"On the one hand, there is nothing new here – we've known for a long time that you could use DNA to store extrinsic information," says Assistant Professor Drew Endy, a leader in the field of synthetic biology. "But on the other hand – holy cow, this is an entire book! You can now go with a straight face to the British government's head of archives and say 'I have something relevant to your problem.'"

Endy says the relatively long retrieval time for genetically-stored data means it won't end up inside our computers. "You may get the retrieval of data down to 10 minutes or 10 seconds, but the strength here is the persistence of information," he says. "Is there something you want to store for 100 or 1,000 years? That's where this gets interesting."

Storing data in DNA also ensures that – unlike floppy disks – the means to retrieve the data will still be around in the future. "Do you think DNA is going to be a relevant molecule to humanity in 100 years' time? Absolutely," says Endy. "Storing data in DNA is the best guarantee that we will be able to read it back later."

TIMELINE

The rise of genetic data storage

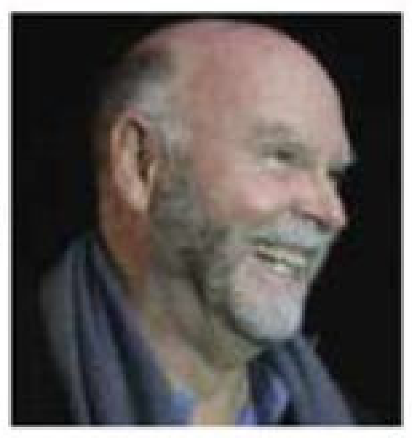
1995
The first genetic sequence of a bacterium is completed by a team at the Institute for Genomic Research in the US.

1998
Artist Eduardo Kac converts a line from the *Bible* – 718 bits of data – into Morse code and then into genetic material, which is added to bacteria.

2001
Two rival teams announce the completion of their draft sequence of the entire human genome – a major advance in gene sequencing.

2009
Canadian researchers encode text, music and imagery in DNA for the first time. A total of 1,688 bits of data are encoded.

2010
Biologist Craig Venter and his team encode a 7,920-bit message, or 'watermark', in the DNA of bacteria they have created to show they are synthetic.



2012
Professor George Church and his team at Harvard Medical School store 5.27 megabits of data, an entire book, in DNA.

WHAT DO YOU THINK?
Let us know your thoughts at facebook.com/sciencefocus

PHOTO: PRESS ASSOCIATION X2, REUTERS, DISNEY/HANNA FUHRMANN, GETTY

Items displayed on touchscreens could be given a realistic texture with REVEL

Technology

Touchy-feely displays

IMAGINE RUNNING YOUR finger across the picture of a dog on your tablet computer's display and being able to feel its fur, or feeling the smooth contours of a car on a poster. These are possibilities raised by new technology that allows you to experience textures that aren't really there.

The idea of augmenting reality with artificial tactile sensations isn't new. But existing systems involve fitting objects with actuators to physically alter them, or the user wearing gloves that produce artificial sensations. Now scientists at Disney Research, the R&D wing of The Walt Disney Company, have found a way to produce sensations without such paraphernalia.

Disney's REVEL technology requires a signal generator just 5cm across that could be attached to the sole of a shoe, or the seat of a chair. This applies an imperceptible electrical signal to your body. When you touch certain objects, an electrostatic force is created that alters the friction between your finger and the surface. By varying the electrical signal, different textures can be simulated.

"REVEL can add tactile feedback to walls, tables, wooden and plastic objects, or even human skin," says Dr Olivier Bau at Disney Research in Pittsburgh. This 'reverse electrovibration' technique does have its limitations – sensations can only be produced when you slide your finger over an object. But it is a promising step.

JAMES LLOYD

1 MINUTE EXPERT

Monster stars

What are monster stars?
Stars that are about 300 times more massive than our Sun, making them the largest ever found. Four were discovered in 2010 in the Large Magellanic Cloud galaxy, about 160,000 light-years away. This puzzled astronomers because, in theory, stars as big as this shouldn't exist.

Why shouldn't they exist?
Until 2010, astronomers had seen stars up to 150 times the Sun's mass, and they could all be explained by the same formation process. But this process could not explain the monster stars.

How did they get so big?
That's been the big question since they were spotted, but astronomers now think they've solved the puzzle. By simulating how this group of stars evolved, astronomers at the University of Bonn found that the four monster stars could have been formed by collisions between two smaller stars that were once in orbit around each other.

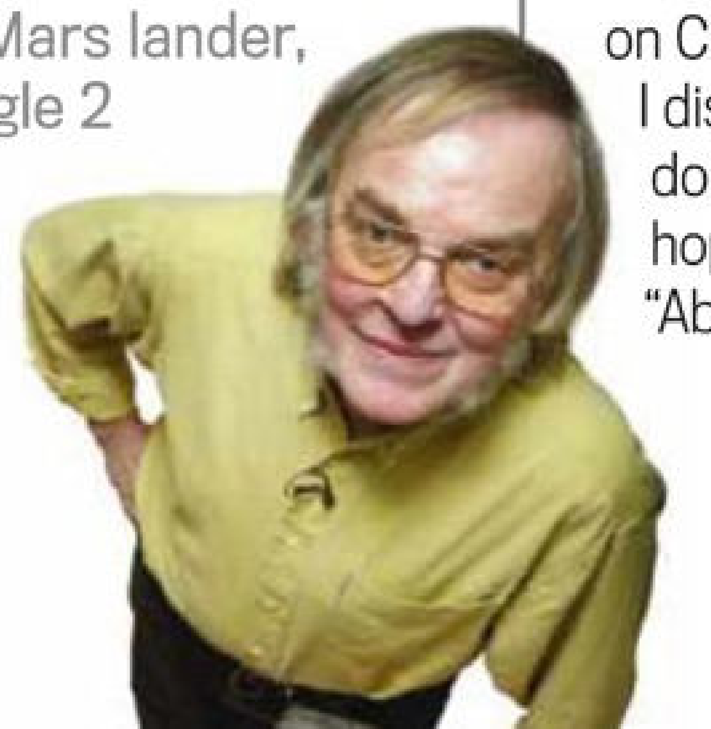
Will the stars always be ultra-massive?
Probably not. In about two million years, these stars' winds will cause them to lose half their mass by blowing off material.

Are there any more monster stars?
So far, no. But astronomers will be keeping their eyes peeled.

WHO'S IN THE NEWS?

Prof Colin Pillinger

Principal investigator for the British Mars lander, Beagle 2



What did he say?
Writing in *The Sun* after NASA's Curiosity rover landed on Mars, he vented his frustration that it's not Beagle 2 looking for signs of life. Beagle was lost on landing on Christmas Day, 2003. "Am I disappointed to see NASA doing the experiments we hoped to do?" he wrote. "About as disappointed as an Olympic athlete who gets to London 2012, only to pull up with a hamstring injury at the first hurdle."

Did he vent his frustration in any particular direction?
Yes, towards the European Space Agency (ESA). He said that what really annoyed him was seeing the hundreds of NASA Mission Control staff monitoring Curiosity's progress. "We had four people trying to receive a signal from Beagle 2, and ESA would not even turn their antenna towards us."

Did this cause a stir?
Pillinger's quotes received plenty of press attention, but ESA didn't react.

Seismology

No link between big 'quakes

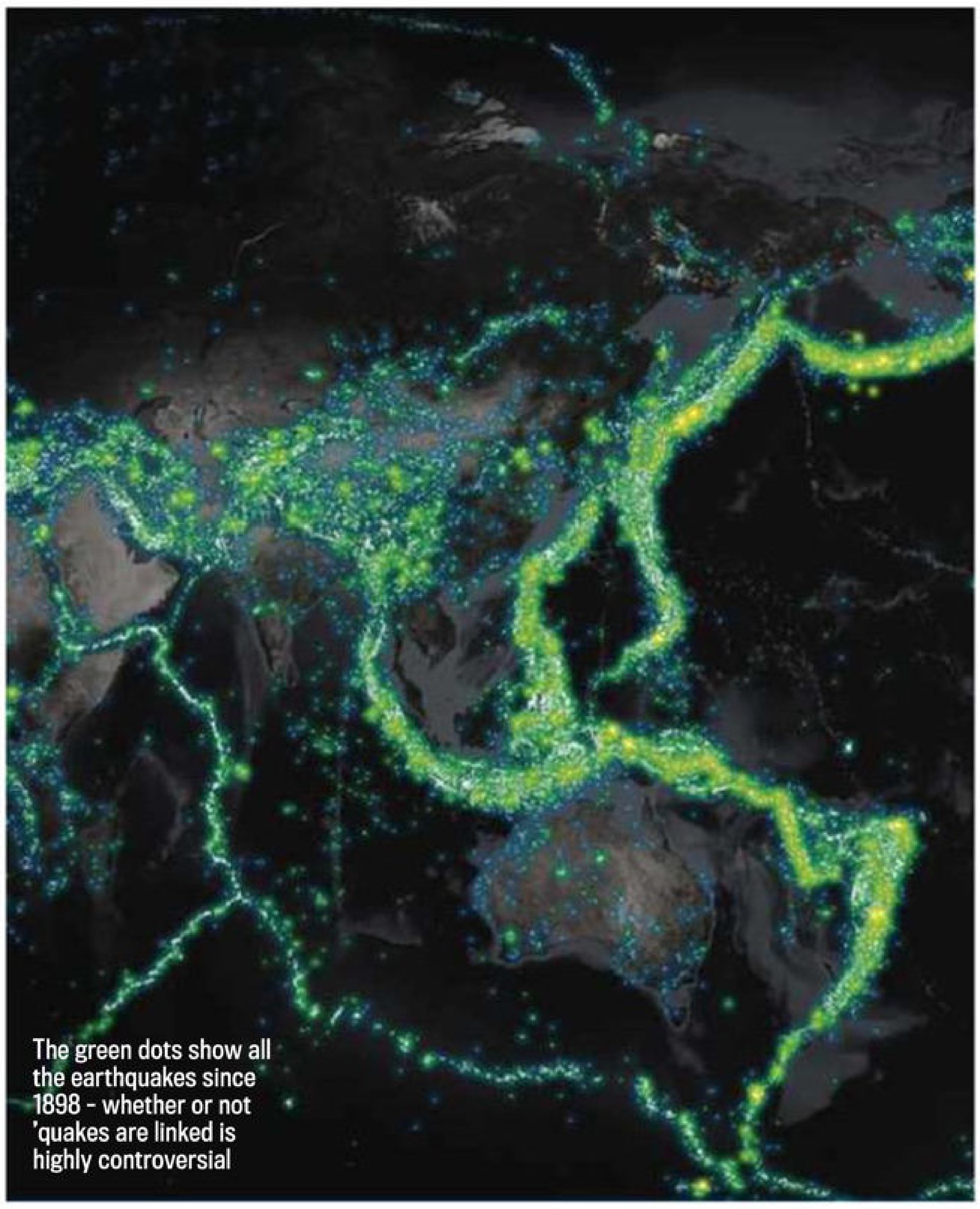
MAJOR EARTHQUAKES occur at random and cannot trigger one another, say researchers in the US. A series of major 'quakes had led to speculation that big shifts in the Earth's crust are linked, one leading to the next. But a new study seems to show this is not true.

Since 2004, Sumatra, Chile, Haiti and Japan have all suffered major earthquakes, and there was a similar clump during the 1960s. Geologists at the US Geological Survey took the record of earthquakes of magnitude 8.3 and above from the last 111 years and compared it to a list of fictional 'quakes generated at random. The intervals between large 'quakes in the two lists were similar.

"Random processes are characterised by clustering," says Tom Parsons, lead author of the study. The biggest rumbles are still known to trigger smaller micro-tremors around the globe. "We're puzzled why large 'quakes should trigger small ones worldwide, but not larger ones," says Parsons.

Not everyone is convinced by the study. "I don't think this provides unequivocal evidence for or against clusters," says Dr Felipe Dimer de Oliveira, of Australia's Risk Frontiers. "A clustered process may be similar to a random process when you look at a small piece of it, as is the case for the 111 years of data we have."

James Lloyd



The green dots show all the earthquakes since 1898 – whether or not 'quakes are linked is highly controversial

PHOTO: JOHN NELSON. NASA. THINKSTOCK

ADVERTISEMENT FEATURE

INKJET MEANS BUSINESS

Faster than colour lasers and half the cost, the award-winning new WorkForce Pro inkjets are the speedy, economical, hassle-free printers to take your business forward

Inkjets can't cut it with the rigours of business life. Right? Not necessarily. Not all inkjets are made in the same way. They can be built to handle the stresses and strains of business use, and work out cheaper to run than the equivalent colour laser – while matching, if not exceeding, the levels of performance and quality that lasers deliver.

As a leading manufacturer of both laser and inkjet printers, Epson understands that colour lasers aren't the best fit for every business, so they've developed inkjet alternatives engineered specifically to meet the needs of the business user.

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Just like business lasers, WorkForce Pro inkjets can be ordered with a built-in duplexer for more economical double-sided printing, and high-capacity paper trays to save on trips to the stationery cupboard.

Direct USB and shared network connectivity come as standard across the WorkForce Pro range, with Wi-Fi connectivity available on selected models. There's a choice of multi-function devices with built-in scan, copy and fax functions for an all-in-one solution. And the WorkForce Pro range can be used with all the leading Windows® and Mac applications.

With the WorkForce Pro range, Epson has re-engineered the inkjet

You won't find these printers in the supermarket aisles, that's for sure. But with the WorkForce Pro range, Epson has re-engineered the inkjet to deliver a comprehensive range of robust, capable and easy to manage printers. Faster than a laser and 50 per cent cheaper, these inkjets really are good for business.

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Space

Tributes to Moon hero Armstrong

One giant leap: Neil Armstrong, the first man on the Moon

QUICK WITTED AND calm, Neil Armstrong was the ideal person to make the first manned landing on the Moon, says Sir Patrick Moore, who has paid tribute to the former astronaut, who has died aged 82. Moore interviewed Armstrong several times after he set foot on the surface of the Moon on July 1969. In *Sky at Night Magazine*, Moore writes: "On meeting him, one was conscious of a quiet confidence that he would be able to tackle any crisis."

With just seconds of fuel remaining in the Apollo 11 landing craft, Armstrong and Buzz Aldrin took their one chance of landing at the Sea of Tranquility. "If they had not taken it and instead blasted back into orbit there would be another 'first man on the Moon'," writes Moore.

A private funeral service was held for Armstrong, who died from complications following heart surgery. Read Moore's tribute in the October edition of *Sky at Night Magazine*.

Andy Ridgway

THEY DID WHAT?!

Strange but true lab experiments

DELIBERATELY BLOCKING THE NOSES OF VOLUNTEERS

What? Neuroscientists at Northwestern University in Chicago sealed up the nostrils of 14 volunteers with surgical tape before making them spend a week in a special low-odour hospital room. These human guinea pigs also ate low-odour food and their noses were only unblocked at night to help them sleep.

Why? After a week, the volunteers had their brains scanned in an fMRI machine to discover how they would react to a cold or hayfever-like blocked up nose.

What did they find? A blocked nose isn't just irritating, it also affects our brains. After the period of odour deprivation, the researchers found an increase in activity in the volunteers' orbital frontal cortex and a decrease in activity in the piriform cortex – two brain regions involved in the sense of smell.

So what does this mean? The neuroscientists say the brain needs ongoing sensory input to maintain and update the smell information it retains. When this input disappears, the changes in the brain are aimed at maintaining these internal representations of odours, so smells can quickly be recognised once the sensory input returns. This means that, unlike other senses, our sense of smell rapidly recovers after a period of deprivation – handy because our noses are often blocked.

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Professional Laser Killer

Speed Prints 16 pages per minute in monochrome and 11 pages per minute in colour. Colour lasers may seem faster, but factor in warm-up time and printing a handful of pages is quicker with an inkjet. Plus, the WorkForce Pro is **50 per cent faster** than the nearest competitor product.

Quality The Micro Piezo head prints in full colour at up to 4800 x 1200dpi, coping with everything from Word and Excel documents to high-resolution photos. Epson DURABrite Ink dries instantly and is resistant to water, smudging, highlighter pens and fading, and can print on a wide variety of media, including CDs and DVDs.

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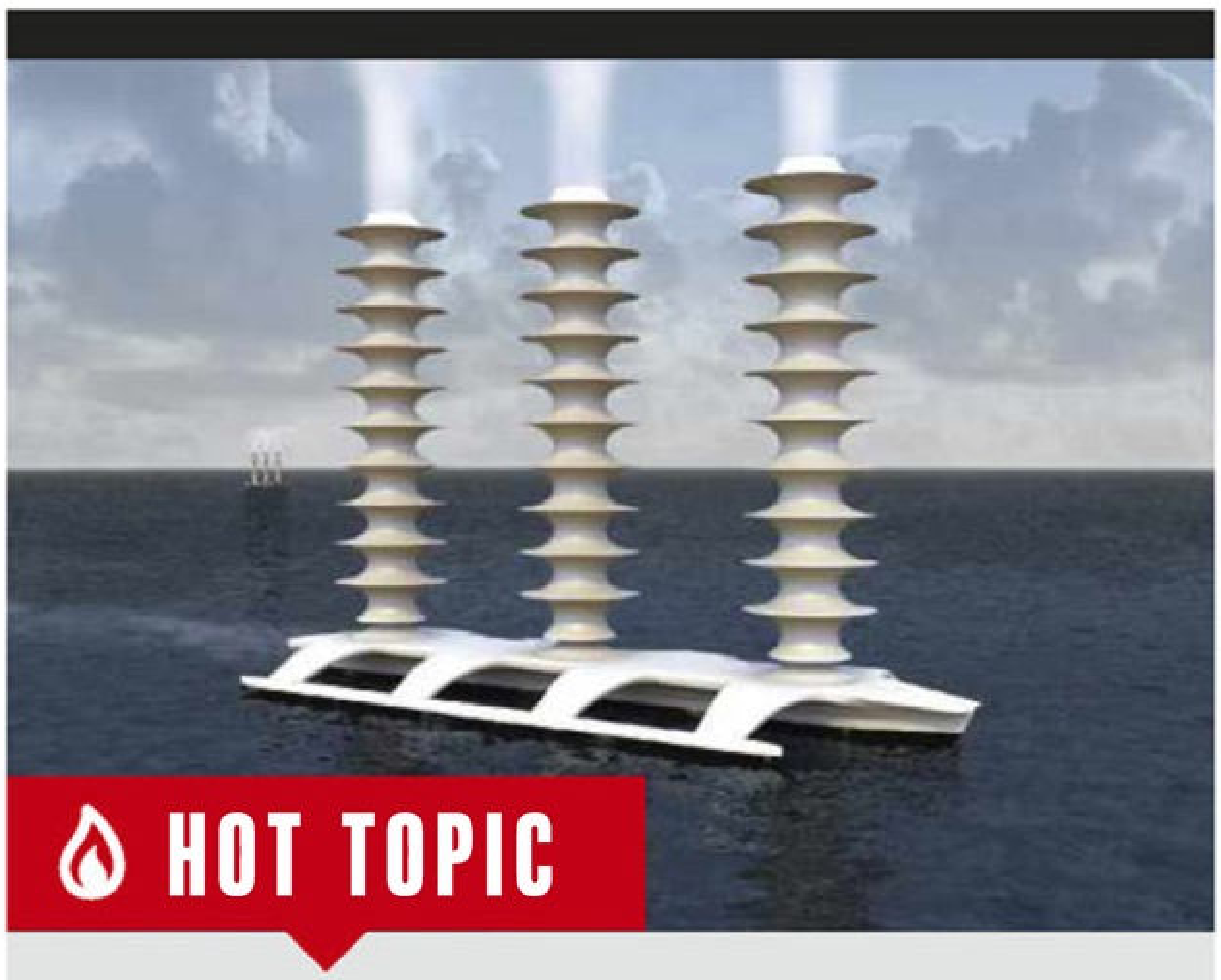

HOT TOPIC

Should cloud geoengineering be tested?

A team of climate scientists led by Prof John Latham at the University of Manchester are suggesting a three-stage test of 'cloud brightening' geoengineering. They propose shooting salt water into the sky to create clouds that reflect sunlight and counter global warming.

In the first phase, sprayers would be deployed on a ship at sea to ensure they can propel sufficient particles of the target size to the correct altitude. Next, aircraft would investigate how the clouds develop. In the final phase, 5-10 ships would pump out sufficient particles to generate clouds whose light-reflecting abilities could be tested by satellites.

"I would rather scientists test the idea than groups that might have a vested interest," says Associate Professor Robert Wood, an atmospheric physicist at the University of Washington. But previous attempts to test geoengineering ideas have fallen on stony ground, with critics arguing that the climate should not be deliberately meddled with.

WHAT DO YOU THINK!

Let us know your thoughts on this using the hashtag **#hottopic** at: **twitter.com/sciencefocus** and **facebook.com/sciencefocus**

Your Tweets and Facebook posts

D.J. Cook: *A good idea imo. They also need to copy reflective sheeting study http://en.wikipedia.org/wiki/Solar_radiation_management#Reflective_sheeting*

Csillagszemmu: *I think, if we'd like to maintain humanity on Earth, and have the power and knowledge, it might be worth a bit of meddling...*

Corey Bump: *Er, anyone here ever watch The Matrix LOL*

Sara Li-Davies: *Meddling? What a fine mess it got us into! Recapture, Replant, Reinvent, to Reverse the Rot whilst we Repent at leisure :((*

Jens Jensen: *This proposal surely beats pumping diverse aerosols and particles into the atmosphere*

PHOTO: JOHN MACNEIL

WHAT THE PAPERS SAY

HENRY GEE

New research from leading science journals

Our genes are revealing some strange relations

ONE OF MY favourite TV shows is *Who Do You Think You Are?*, in which a celebrity traces his or her ancestry, revealing unlooked-for surprises and startling revelations. The accessibility of census data and other public records means it's never been easier to trace one's ancestry.

As for individuals, so for humanity in general. Over the past year or so, a flood of genetic data has begun to reveal some surprising twists in the ancestry of us all. More than a decade after the first human genome was sequenced, human genetic sequences are ten-a-penny; we can now also extract and sequence genomes from extinct relatives such as Neanderthal man. And these developments are revealing just how complicated our history is.

Modern humans (*Homo sapiens*) evolved in Africa around 200,000 years ago. Conventional wisdom has it that some of these early members of our species left Africa to colonise the rest of the world, replacing all other hominins (members of the human family of species), which became extinct. This scenario is supported by a great weight of evidence. Firstly, human genetic diversity is rather low; secondly, what genetic diversity we do have is concentrated in Africa. But new genetic data shows that modern human migrants didn't, in fact, completely replace other hominins.

The first revelation, in May 2010, was that up to four per cent of the DNA in modern Europeans is of Neanderthal origin. In the same year came a report on a finger bone fragment found in Denisova cave in Siberia. The bone is unremarkable apart from the fact it contains the genome of a previously unknown species of hominin – a genome that has left traces in many people living today in south-east Asia and Melanesia.

It turns out that all over the world, humans bear genetic traces of older hominins. In many cases, these genetic quirks are the only knowledge we have that these species existed. A paper published in *Cell* this summer showed that the genomes of African hunter-gatherers such as pygmies contain small amounts of DNA inherited from otherwise unknown species of hominin.

Over the past year or so, evidence like this has profoundly changed our view of ourselves. We now know that we're a complex collection of DNA from disparate sources. The genetic results have caused anatomists to dust off skulls and skeletons that always seemed too odd to fit into modern human species, especially in Africa.

So, are there any ancient skeletons in *your* cupboard? You betcha.

Henry Gee is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*

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US students are trying to build a bacterium that could survive the conditions on Mars

Synthetic biology

Bacteria being created to live on Mars

MICROORGANISMS ARE being kitted out with genes that would enable them to withstand tough conditions on Mars and aid human colonisation. Mars is an inhospitable place, with average temperatures of –50°C, an almost non-existent atmosphere and high levels of radiation. But US students at Brown and Stanford universities hope to develop a series of 'BioBricks' that would enable a bacterium to survive on the Red Planet and act as a workhorse. BioBricks are sequences of DNA that perform a particular function and can be added to a cell.

DNA can be added to cells to bestow new properties

"If we wanted to establish a base on Mars or the Moon, sending up all the machinery needed to survive in space would take a huge chunk of change," says Ben Geilich, a student at Brown and head of the 'Hell Cell' project. Instead, genetically engineered bacteria could provide food, medicine and even building materials.

Geilich and his team are entering this year's International Genetically Engineered Machine (iGEM) competition, in which students from around the world are designing new genetic tools that work in real life organisms. "We aim to create a suite of BioBricks to provide resistances to extreme temperature, pH, radiation and desiccation," says Geilich. "These bricks could then be plugged into a microorganism that you've engineered to perform a useful function." Among the genes being investigated are some from a cold-resistant species of Siberian beetle that makes antifreeze proteins.

As well as plundering genes, the Hell Cell team will see how well they would work in *Escherichia coli*, a ubiquitous bacterium. The team will present their ideas at a regional iGEM competition in October, hoping to win a place in the world finals in November.

DIGITAL WORLD

Science on the web

AXON

axon.wellcomeapps.com

Ever fancied growing some extra brain cells? Now you can – in digital form, at least. Axon is a game created by the Wellcome Trust in which you compete to see how long a nerve cell, or axon, you can grow. Through this slick site you'll discover how the building blocks of your brain develop.

CURIOSITY

mars.jpl.nasa.gov/msl/multimedia/raw/

Mars rover Curiosity touched down in August and immediately began snapping pictures of its new surroundings. Here you can see all of the raw images it sends back, courtesy of NASA's Jet Propulsion Lab. The car-sized rover will send data back to Earth for at least two years, so it's worth checking back regularly.

Keep up with the latest data from Curiosity at this dedicated NASA microsite

BODY PODS

fueltheatre.com/projects/body-pods

You'll see your body in a whole new light thanks to this series of podcasts in which an artist explores everything from your hand to your heart with guidance from an expert. There's music, poetry, sketches – all brought together to bring a new perspective on your inner workings.

SDSS III DR9

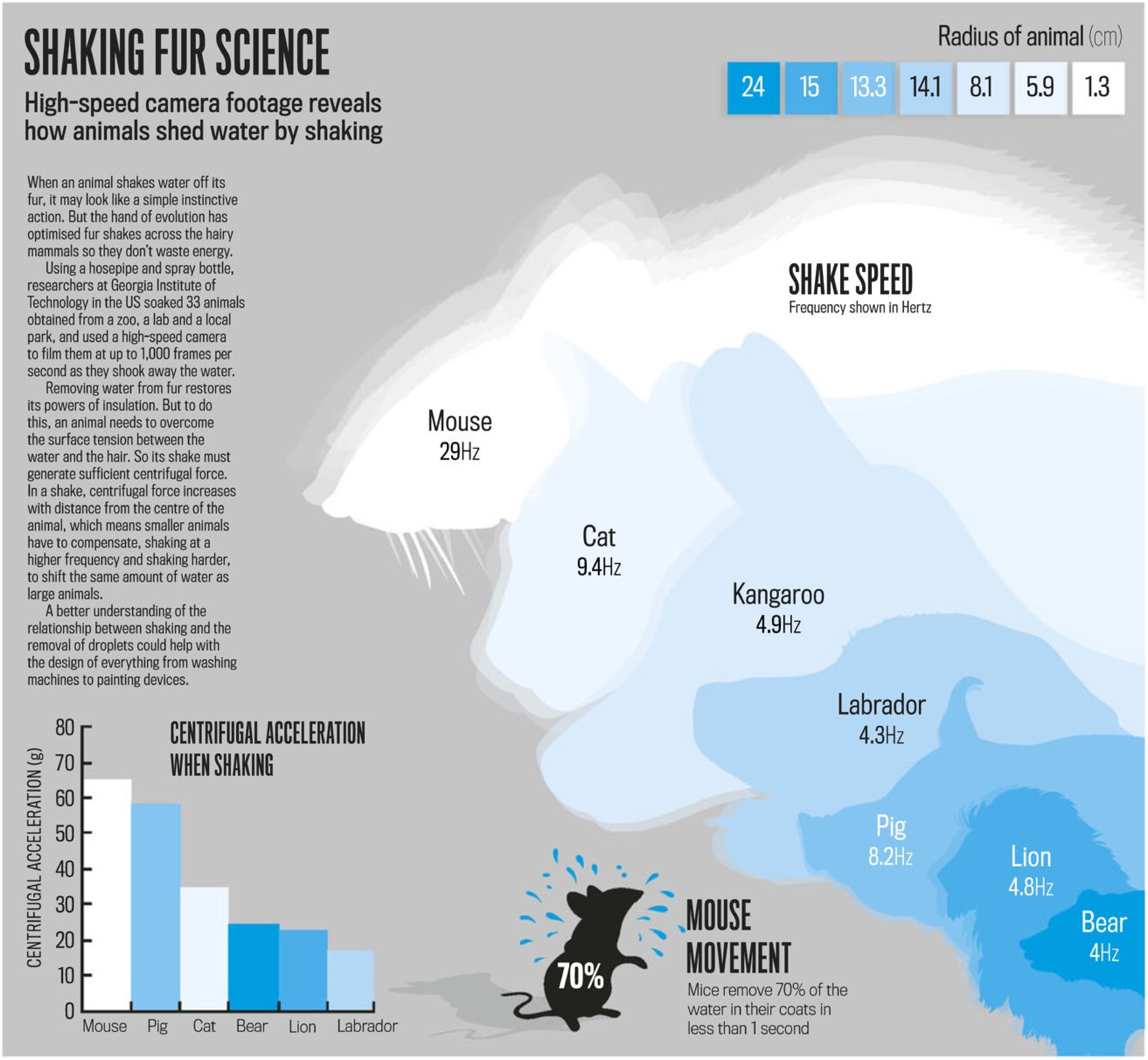
sdss3.org/dr9

Armchair astronomers, take note: the biggest ever 3D map of massive galaxies and faraway black holes has just been released. You can fly through the newly mapped regions of space in a video created by the Sloan Digital Sky Survey, and download data the collaboration has collected using its telescope in New Mexico. It's fairly technical, but there are tutorials.

PHOTO: NASA, THINKSTOCK, LYNN ROTHSCHILD

SHAKING FUR SCIENCE

High-speed camera footage reveals how animals shed water by shaking



When an animal shakes water off its fur, it may look like a simple instinctive action. But the hand of evolution has optimised fur shakes across the hairy mammals so they don't waste energy.

Using a hosepipe and spray bottle, researchers at Georgia Institute of Technology in the US soaked 33 animals obtained from a zoo, a lab and a local park, and used a high-speed camera to film them at up to 1,000 frames per second as they shook away the water.

Removing water from fur restores its powers of insulation. But to do this, an animal needs to overcome the surface tension between the water and the hair. So its shake must generate sufficient centrifugal force. In a shake, centrifugal force increases with distance from the centre of the animal, which means smaller animals have to compensate, shaking at a higher frequency and shaking harder, to shift the same amount of water as large animals.

A better understanding of the relationship between shaking and the removal of droplets could help with the design of everything from washing machines to painting devices.

MOUSE MOVEMENT

Mice remove 70% of the water in their coats in less than 1 second

NEWS IN BRIEF

Elephant talk explained

A team of biologists passed air through the larynx of a recently-deceased elephant to discover how they generate their very low frequency vocalisations. They found these noises are produced when air from the lungs causes the vocal chords to vibrate – just like in humans – rather than the voice box muscles being actively controlled, as they are in purring cats.

Elephants' voice boxes work like those of humans, rather than like those of cats

India heading to Mars

Four years after its first Moon mission, India is planning its first visit to Mars. The Indian Space Research Organisation plans to launch an unmanned orbiter, which will study the planet's geology and climate, in November 2013. With the first Chinese mission to Mars failing last year, this could be India's attempt to get ahead in the Asian space race.

Spider tech to heal planes

Tiny cracks in aircraft bodies could be healed using a technique borrowed from spiders' webs. Spider web fibres relax and contract in response to temperature and humidity. Now researchers have developed artificial versions from polyurethane polymers that contract when heated, drawing a structural 'wound' together before plastic particles melt into the gap.

PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd

Gaming is about to get physical

MICROSOFT IS LOOKING to take motion-sensing gaming to the next level. Imagine a cricket game where the tiniest flick of the batsman's wrist can change the direction of the ball, or a beat 'em up which monitors every flex of your biceps.

The computing giant recently invented a controller that detects and decodes the electrical signals produced by muscle activity, a technique known as electromyography. Surface sensors placed on the body pick up the signals before they are interpreted. The sensors could be embedded in an armband, wristwatch, shirt or pair of gloves.

Microsoft says the system is user friendly because gamers don't need to place the sensors precisely on their bodies. More sensors are built into the controllers than are required to measure muscle movement and the system can select the ones that will give accurate readings.

As well as enhancing the gaming experience, the technology provides a way to communicate with gadgets such as TVs and smartphones. A driver could even activate the sat-nav device simply with a nod of the head.

Patent application number: US 20120188158

Motorbike jacket gets a parachute

CRASH HELMETS ARE all well and good, but how do you protect a biker's torso in a pile-up? Corey Cooper in Alabama has come up with a novel solution – give them a safety jacket with a parachute.

In the event of a collision, the motorcyclist pulls a release lever, causing a parachute to shoot rearwards. This decelerates the wearer, ejecting them from the bike and reducing their chances of being injured.

Once activated, the jacket – which has already been granted a patent by the US Patent and Trademark Office – works in a similar way to a car's airbag. Pulling the lever causes an electric current to flow into a propellant canister, where a solid fuel is ignited. This starts a rapid chemical reaction within the canister, generating gas that forces the parachute out of the back of the jacket.

Patent number: US 8240610

Security camera repels spiders

EXISTING INFRARED LED security cameras present a warm spot that attracts spiders, which spin their webs and catch prey in front of the lens – obscuring the image. But now South Korea's Yoon Hwa Ko has been granted a UK patent for an anti-spider security camera. It emits ultrasonic waves when the temperature and humidity reach spider-friendly values, deterring the creepy-crawlies.

Patent number: GB 2457805

Don't get too close! These termites have a short fuse

PHOTO: R HANUS/SCIENCE, ROBIN BOYDEN

Microbiology

The case of the exploding termites

ELDERLY MEMBERS OF a termite species have been found to explode when under attack, releasing a poison that kills or paralyses their enemies. A team of biologists first chanced upon members of the species *Neocapritermes taracua* while trekking in French Guiana. When they tried to pick up one of the termites, which had blue spots on its back, it ruptured. Further investigation showed that older workers – which are less able to forage – carry blue pouches that act as explosive backpacks and contain copper-rich protein crystals. The protein is thought to convert a non-toxic substance in the salivary glands into something deadly. **Penny Sarchet**

LG Life's Good

LG optimus 4X HD

LG Optimus 4X HD

This powerful new Quad-Core smartphone from LG has all the connectivity options you could ever hope for

Get your hands on the new LG Optimus 4X HD and you'll struggle to decide what you like most about this thin, light smartphone with its clean interface and multitude of cutting-edge features.

Powered by Google's latest Android 4.0 operating system, aka the 'Ice Cream Sandwich', this impressive smartphone has a 1.5GHz NVIDIA® Tegra® 3 Processor – the world's only 4-PLUS-1™ Quad-Core Mobile Processor. With a massive 12 Core GPU, it is designed for high speed and multi-media performance, and also utilises a fifth battery-saver core to handle less demanding tasks.

The ingenious combination of True HD and IPS guarantees you'll enjoy life-like colour clarity, whether you're indoors, outdoors, or viewing from wide angles. And the 313 ppi Stripe RGB Panel creates sharper and crisper letters.

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You know life's good when you have such speed, performance and endurance in the palm of your hand.

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Memory 16GB / 1GB (DDR2) / SD card slot gives up to 64GB

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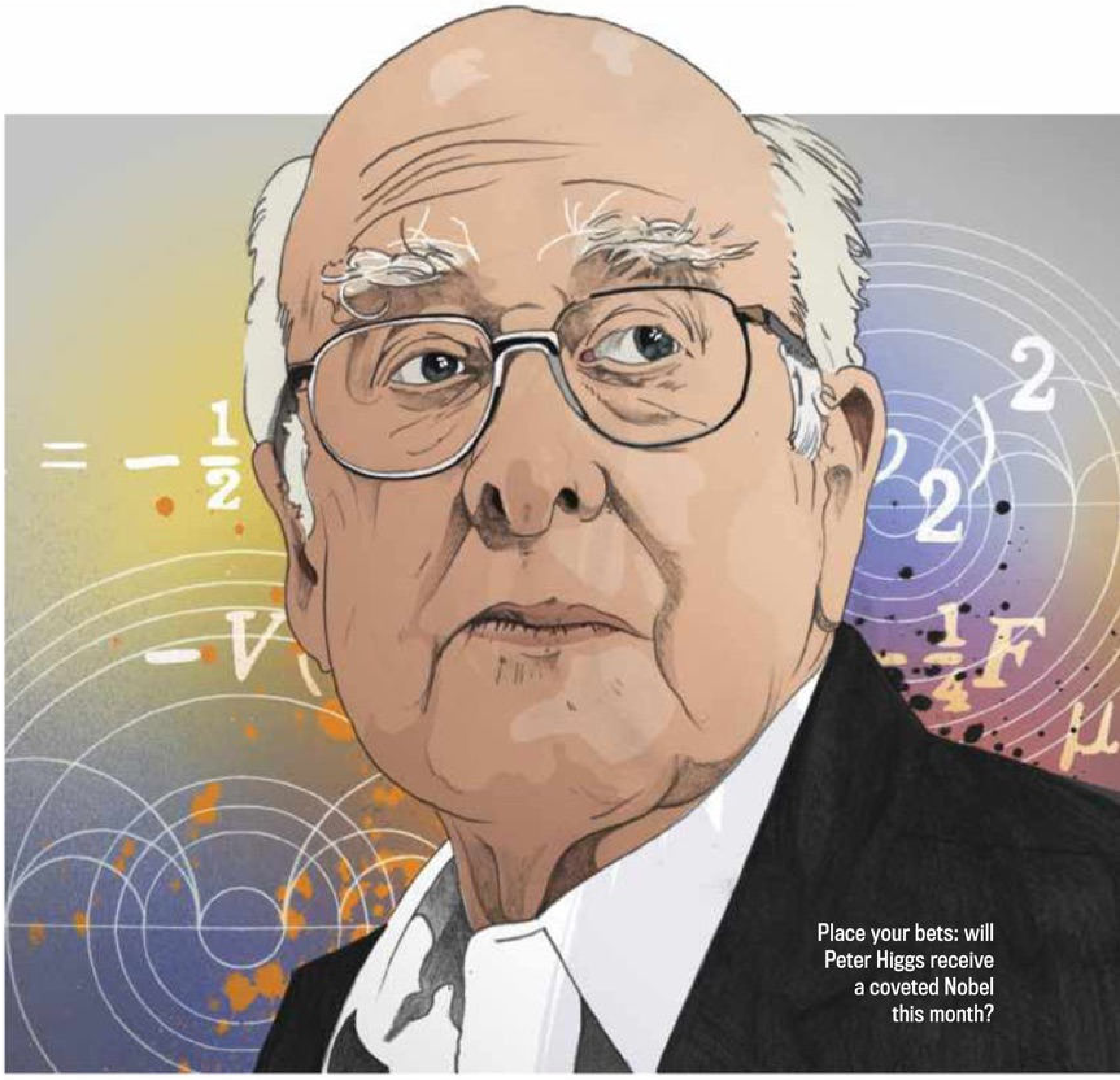
INSIDE SCIENCE

ROBERT MATTHEWS



Place your bets: will Peter Higgs receive a coveted Nobel this month?

Never mind the mystery of dark matter, the origin of the Universe and the Theory of Everything. Right now, the big puzzle occupying some of the most brilliant minds on Earth is this: will a kindly English octogenarian finally win the Nobel Prize?

Even those who don't know a boson from a boatswain have twigged that someone called Professor Peter Higgs once suggested a particle might exist, and that scientists may now have found it. But anyone who does have an idea of the significance of the Higgs boson is pondering the knotty matter of whether the eponymous theorist will win the Nobel Prize for Physics this month.

Few doubt that Prof Higgs deserves a Nobel. After all, he has played a key role in paving the way to the ultimate Theory of Everything that it's hoped will reveal the cosmic unity of all particles in nature and the fundamental forces that act on them. Put simply, during the 1960s some theorists found a way of unifying two of these fundamental forces: the electromagnetic force and the so-called weak force, which affects atomic nuclei. It was a brilliant achievement, boosting confidence in the underlying unity of nature.

Indeed, so brilliant was it that its principal architects shared the 1979 Nobel Prize for Physics – years before its predictions were actually confirmed by scientists at CERN (home today of the Large Hadron Collider, or LHC). But there was a problem: the basic theory implied that particles did not have mass, which anyone with a set of bathroom scales knows is cobblers. Prof Higgs was among those offering a solution: a cosmic force field that imbues certain particles with the property we call mass – and whose existence is revealed via a particle called the Higgs boson. And now scientists at the LHC think they have found it.

> **"Even if the Higgs particle is confirmed, Prof Higgs is just one of at least five theorists with a claim for sharing the Nobel Prize"**

So why wouldn't the Nobel Committee award Prof Higgs the prize? Because, as so often in science, things aren't as simple as they seem. For starters, the Higgs hasn't been found; so far, all that can be said with some certainty is that the LHC has found a particle with some of the expected properties. Some more 'ID checks' are currently underway to ensure the particle isn't an impostor, as some theorists have shown could exist. Ruling that out will need more data analysis, and months of number-crunching.

The Nobel Committee really took a punt in giving the three architects of 'electroweak unification' the prize back in 1979. It might not want to risk that again, as such punts have sometimes gone wrong. Back in the 1920s it awarded a Nobel to a Danish doctor who had 'proved' cancer is caused by a microscopic worm. Sadly for all concerned, it isn't.

But even if the Higgs particle is confirmed, there's another problem: Prof Higgs is just one of at least five theorists with an excellent claim for sharing the prize – and the Nobel cannot be split more than three ways. The Committee has tried quietly leaving out scientists with good claims before, and ended up getting a kicking from the media.

You can bet the Committee will get another kicking from the media if it fails to give Prof Higgs the prize this month. Even so, my money is on the Nobel Committee waiting until the identity of the newly found particle has been put beyond doubt. It will be interesting to see whether this august institution goes the way of so many others and caves in to media pressure, or does the right thing by science and holds off until the evidence is beyond reasonable doubt. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

ILLUSTRATOR: MATTHEW HOLLINGS

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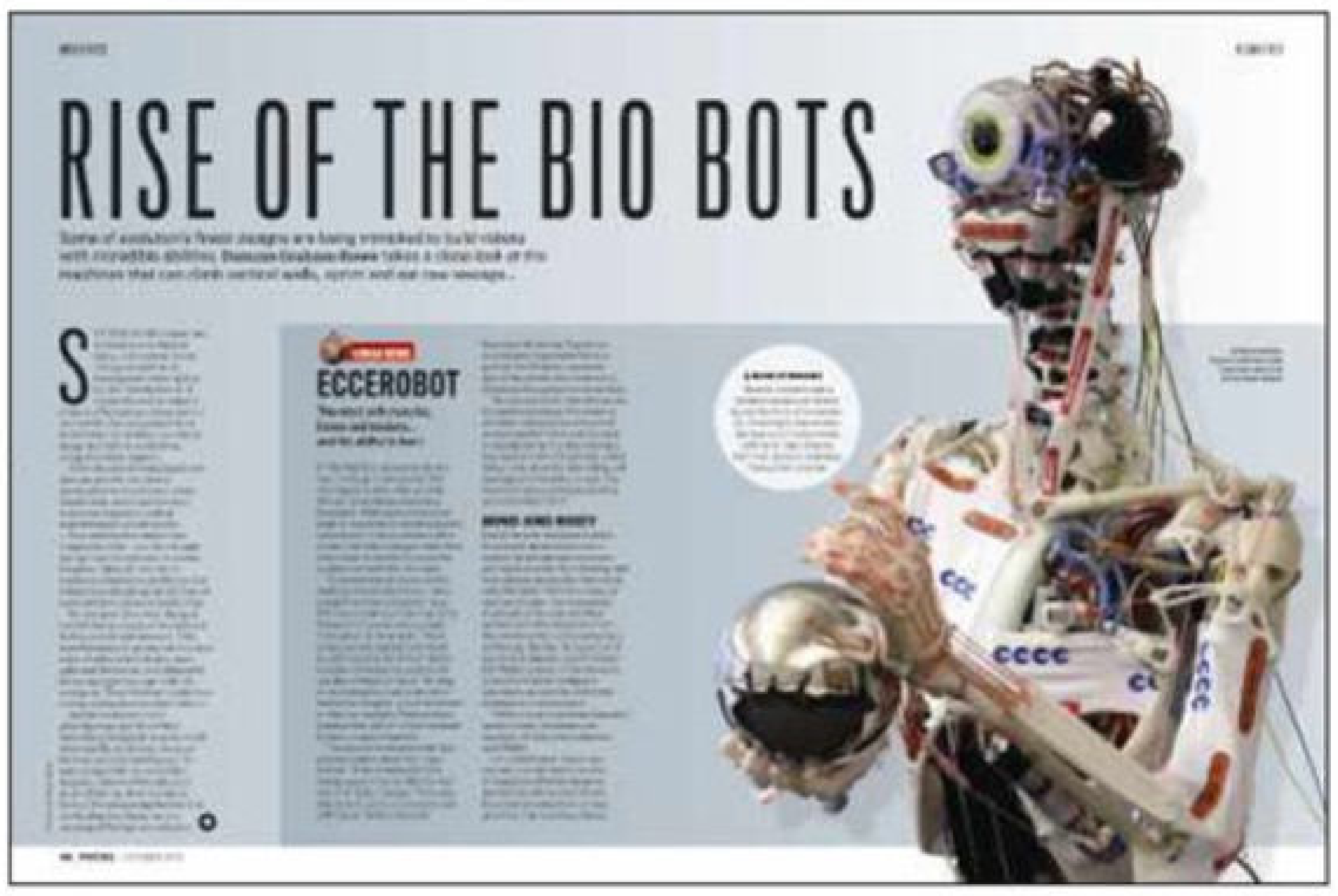

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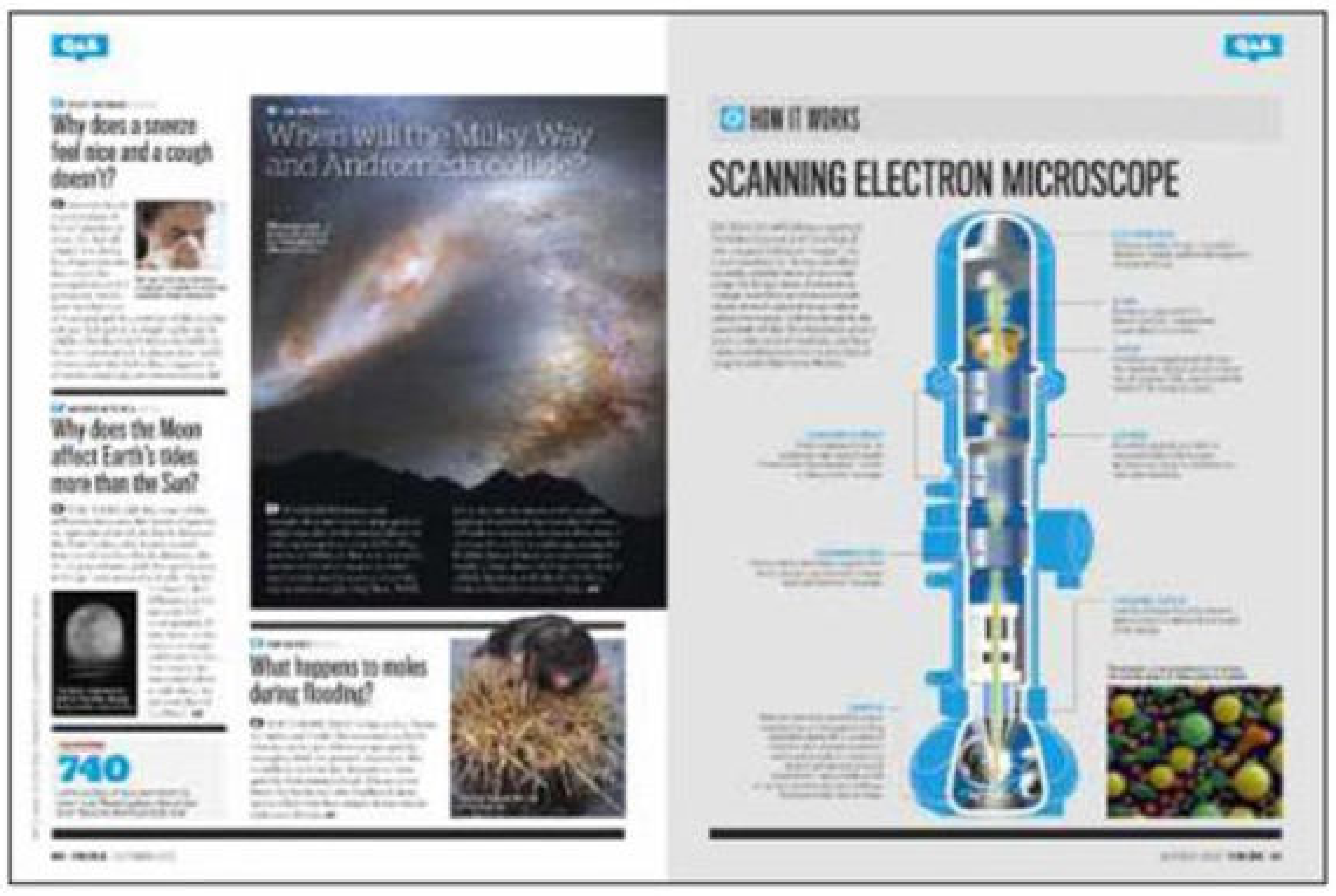
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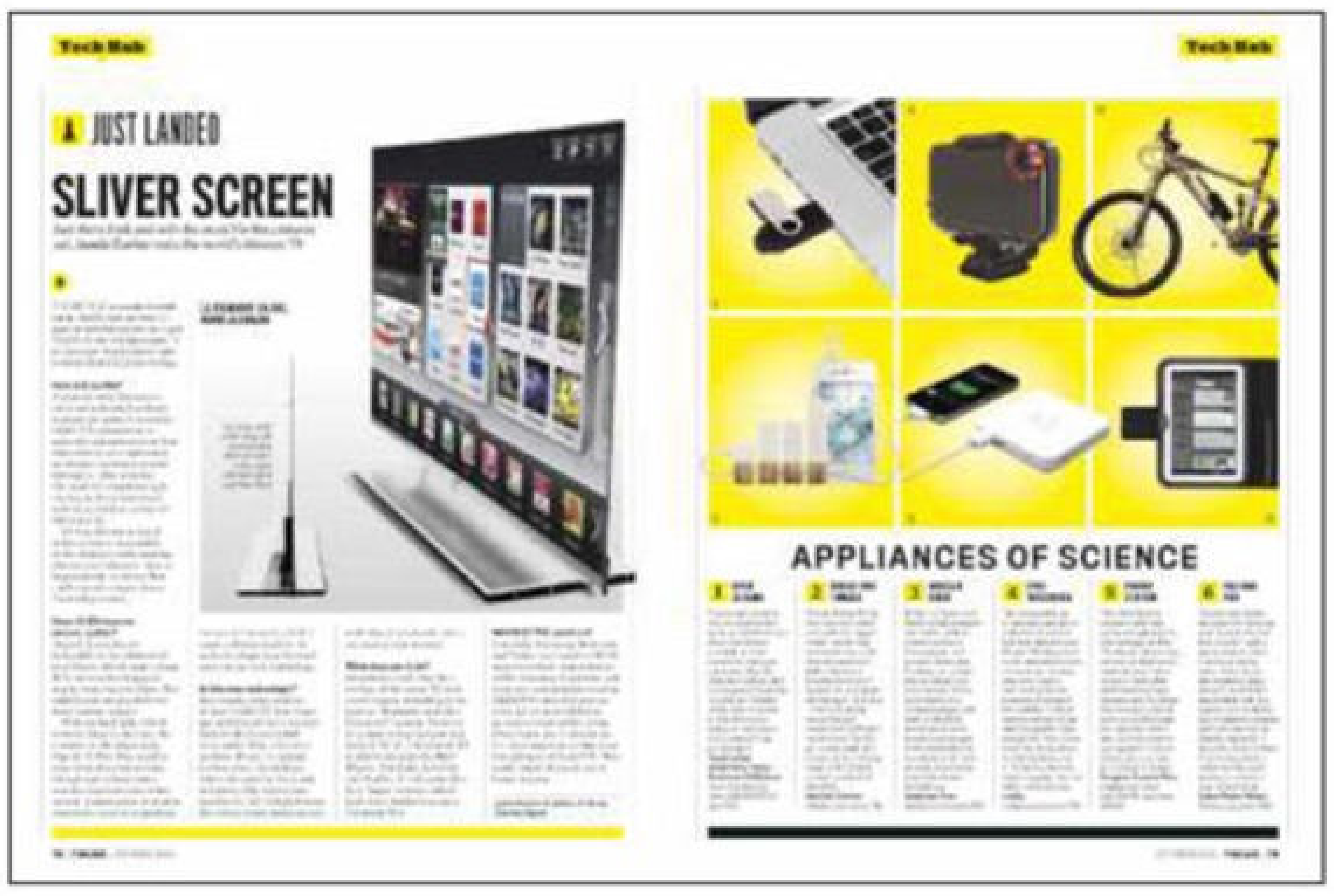

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A laser from the Very Large Telescope pierces the night sky above the Atacama Desert – its successor, the European Extremely Large Telescope, will be able to see the light from alien worlds

PHOTO: ESO

THE SEARCH FOR EARTH'S TWIN

With the discovery of worlds outside our Solar System now commonplace, **Stuart Clark** investigates whether we're about to find a planet just like ours

WHAT BEGAN as a trickle of planetary discoveries in the mid-90s has turned into a flood of alien worlds. Today, more than 700 planets orbiting stars outside our Solar System have been detected and the number keeps rising.

But astronomers don't just want to count them, they want to know what it would be like to stand on one. After all, these worlds orbiting other stars – exoplanets as they are known – are likely to take many forms. Some could be covered with water, while others have been predicted that could be entirely made of diamond. But perhaps the most intriguing prospect is that a world just like ours, a twin of Earth, could exist out there in the darkness.

"People always ask me whether I think we will find a planet just like Earth and I always answer 'absolutely yes'," says Professor Sara Seager, one of the world's leading authorities on exoplanets at the Massachusetts Institute of Technology. "When they ask *when* we'll find Earth's twin, I say 'that depends, it's a long story'."

Later this year, the summit of the Cerro Armazones mountain in Chile will be levelled off so a telescope that has the potential to find a twin of Earth can be built. When it's completed, the European-Extremely Large Telescope (E-ELT) will be the world's biggest eye on the sky, with a light-collecting mirror that's just under 39m across – around four times the diameter of any previous telescope.

This new super 'scope will not only enable astronomers to detect the presence of never-before-seen worlds by allowing them to spot the distinctive 'wobble' their gravity generates in their nearby star, but also to characterise them by analysing the light they give off. The characteristics of this light can reveal which gases are present in a planet's atmosphere and therefore whether it has oceans – even whether it plays host to life (see 'The scope that can spot alien worlds', on p38).

Astronomers are currently limited in their abilities to investigate exoplanet atmospheres. They can only study planets that are significantly larger than Earth and generally have to rely on the world passing in front of, or 'transiting', its parent star from our perspective, so the star's light shines through its atmosphere. This doesn't happen often. But the E-ELT's vast light-gathering mirror will allow astronomers to see not only a parent star, but also to peer directly at the dim glow of a neighbouring Earth-sized planet. "To separate a star from a planet you need incredibly sharp images and you only get those with an incredibly large telescope like the E-ELT," says Dr Joe Liske, an astronomer with the European Southern Observatory, the organisation building the E-ELT.

> **"Characterising an Earth-like planet orbiting a Sun-like star is a super-exciting prospect"**
>
> Dr Joe Liske, an astronomer with the European Southern Observatory

160 billion star-bound planets exist in the Milky Way Galaxy alone, the authors of one study published in January 2012, estimate.

"Potentially being able to characterise an Earth-like planet orbiting a Sun-like star is a super-exciting prospect," says Liske. "It's one of the reasons the astronomy community in Europe is so strongly behind this project."

THE CONTENDER

But the £838 million E-ELT is not the only new super 'scope on the horizon. Another international team, this time involving astronomers from the US, China and India among other countries, plans to build a telescope with a 30m mirror at the summit of Mauna Kea in Hawaii, a docile volcano that last erupted 4,600 years ago. Although it is slightly smaller than the E-ELT, the team behind the Thirty Meter Telescope (TMT) still has hopes of detecting biomarkers, the gases that are indicative of life, in the atmosphere of an Earth-like world. And they could beat their European competitors to it – the aim is to complete the construction of the TMT in 2018, four years ahead of the E-ELT.

The current king of exoplanet spotting is NASA's Kepler space telescope. Launched in March 2009, it is peering at over 100,000 stars in a small patch of our Galaxy, spotting exoplanets by detecting the dip in light they produce when they pass in front of their parent star. It has already had a lot of success, having racked up 115 alien world discoveries and more than 2,300 suspected planets ready for follow-up studies. Kepler simply detects exoplanets rather than characterising them in any detail, but Seager is confident one of the stars in the telescope's sights hosts an Earth-sized world

The mountain-top location of the European Southern Observatory's family of 'scopes, soon to be joined by the E-ELT, in Cerro Armazones, Chile

PHOTO: NASA X2, SCIENCE PHOTO LIBRARY, ESO X2

A HOME FROM HOME

The characteristics required for a planet to be Earth's twin

☒ **Placement in the habitable zone**
The habitable zone is where the planet is at the right distance from its star – and therefore the right temperature – for liquid water to exist on its surface. The distance is defined by characteristics of the star and the planet.

☒ **A nearly circular orbit**
This means the planet will always intercept the same amount of life-giving energy from its central star. Most life on Earth depends on this constant flow of energy.

☒ **A stable star**
Solar storms and flares pump dangerous levels of radiation into space. Earth's magnetic field mostly protects us here at the surface, but could be overwhelmed if the Sun were much more active.

☒ **A Sun-like star**
This offers a good compromise between heat and long life. The Sun's longevity is an estimated 10 billion years, allowing plenty of time for life to develop and flourish.

☒ **Earth's mass**
A similar mass to Earth's will attract potentially breathable gases. However, Venus has Earth's mass but suffers sulphuric acid rain and a surface hotter than an oven, so is not habitable.

☒ **Volcanic activity**
Earth is replenished over geological timescales by the recycling of its crust through volcanoes. This can return life-giving carbon to the atmosphere that has been locked away in rocks.

☒ **A large moon**
The gravitational effects of the Moon hold the Earth's axis stable. Without the Moon, Earth's pole would dip further towards the Sun over millions of years, creating climate change.

THE THREE BEST CONTENDERS

The most Earth-like planets we've discovered so far

KEPLER-22B

This planet was hailed as a 'new Earth' when its discovery by the Kepler space telescope was announced in December 2011. It was the first known transiting planet to orbit in the habitable zone of a Sun-like star. Located 600 light-years away, its radius is roughly 2.4 times that of Earth's. In spite of some similarities it is highly likely the planet is entirely covered by water, its ice completely melted.

GLIESE 581 G

Just 22 light-years from Earth, this world is thought to be three to four times the mass of our planet and slap bang in the middle of its star's habitable zone. The trouble is, not every team that analyses the data thinks it exists. Its parent star is a red dwarf that hosts at least four undisputed planets. One of these planets is at the outer boundary of the star's habitable zone.

GLIESE 667 Cc

The second planet around the star Gliese 667C orbits in just four weeks. This proximity makes up for the weaker light from the star, which has a mass of one-third that of the Sun and so is a red dwarf. The planet is a super-Earth, with a mass of around 4-5 times that of our planet. At just 22 light-years from us it is relatively nearby. The star itself is part of a triple star system.

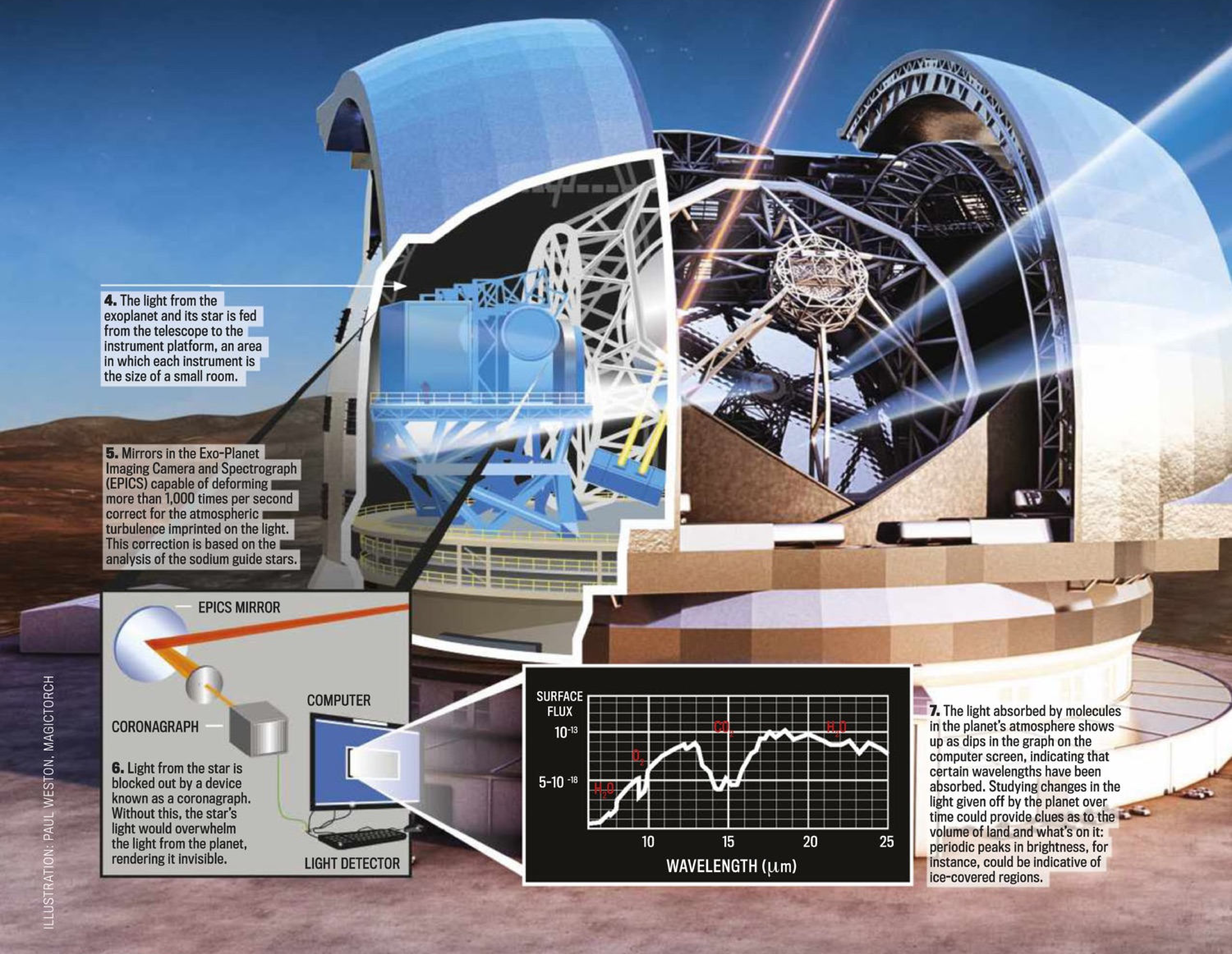
THE SCOPE THAT CAN SPOT ALIEN WORLDS

The European Extremely Large Telescope will have to create its own stars to find planets just like ours

The E-ELT has been designed with the quest for Earth's twin in mind. Its huge mirror – nearly as wide as an Olympic-sized swimming pool is long – will collect light that bounces off the surfaces of worlds several billion kilometres away. As light travels through an exoplanet's atmosphere, molecules within it absorb specific wavelengths, leaving 'fingerprints'. These signatures provide a picture of what the planet is like. Large amounts of water vapour would indicate the presence of oceans, whereas high levels of oxygen, methane and nitrous oxide would be a strong indication that life is present.

The telescope will be built in an ideal location for astronomy – the Atacama Desert is the driest place on Earth with mostly cloud-free days. There is also relatively little turbulence in the atmosphere to shift air around and change the ease with which light from stars can pass through. This means stars are not as blurred and twinkle in the night sky less than they would elsewhere, making it relatively easy to distinguish between light from a star and its planet.

But there's still some distortion from the Earth's atmosphere and that's where artificial stars and a shape-shifting mirror will come in handy.



3. Lasers produced by the E-ELT make naturally occurring sodium atoms glow in the atmosphere about 90km (50 miles) up. These 'guide stars' are perfect spots and the distortion caused to them by the atmosphere is measured.

4. The light from the exoplanet and its star is fed from the telescope to the instrument platform, an area in which each instrument is the size of a small room.

5. Mirrors in the Exo-Planet Imaging Camera and Spectrograph (EPICS) capable of deforming more than 1,000 times per second correct for the atmospheric turbulence imprinted on the light. This correction is based on the analysis of the sodium guide stars.

6. Light from the star is blocked out by a device known as a coronagraph. Without this, the star's light would overwhelm the light from the planet, rendering it invisible.

7. The light absorbed by molecules in the planet's atmosphere shows up as dips in the graph on the computer screen, indicating that certain wavelengths have been absorbed. Studying changes in the light given off by the planet over time could provide clues as to the volume of land and what's on it: periodic peaks in brightness, for instance, could be indicative of ice-covered regions.

ILLUSTRATION: PAUL WESTON, MAGICTORCH

1. The light from a star collides with an orbiting planet and is reflected from its surface. Some of this light is absorbed by molecules in the planet's atmosphere and the rest scatters into space.

2. The planet's light travels through space, along with the star's light, relatively undisturbed for years. During the final second of its journey, the Earth's atmosphere blurs this light.

ALIEN HUNTERS

Analysing the atmospheric gases of exoplanets isn't the only way to find out whether we're alone in the Universe

The Allen Telescope Array's antennae scour the night sky for signs of intelligent life

SETI

At the Big Ear radio telescope, Ohio, in 1977, the astronomer Jerry Ehman picked up a strange signal. It had the hallmarks of an artificial source, but after 72 seconds wasn't picked again. Its origin remains a mystery. Dubbed the 'Wow!' signal after Ehman scrawled the word on the computer readout, it's the closest we've come to listening to aliens.

Maybe the private organisation, the Search for Extraterrestrial Intelligence (SETI) Institute in California, will have better luck. It is now targeting all planetary systems found by Kepler, especially those with planets in habitable zones, and hopes to pick up any messages beamed into space from them. The search was interrupted in April 2011 when budget woes forced its principal partner, University of California, Berkeley, to withdraw from the telescope they shared, the Allen Telescope Array (ATA). But the SETI Institute raised new funds and recommenced work last December.

Asteroid mining

Infrared telescopes may offer a way to spot technologically advanced civilisations. Dr Duncan Forgan at the University of Edinburgh has studied infrared emission from asteroid belts and believes that any mining activity could be recognised. First, the heat and dust generated by mining operations would be detectable by infrared space telescopes such as the Herschel Space Observatory. Second, studying the light spectrums of dust clouds would reveal whether precious metals such as platinum were present in reduced amounts.

City lights

Another way to detect life is to look for the light from alien cities – an idea put forward by Professor Abraham Loeb at Harvard University and Professor Edwin Turner at Princeton University. A 50km-wide city like Tokyo emits enough light to be easily visible with existing 'scopes if it were on Pluto. A space telescope more than 100 times wider than Hubble could potentially see city lights on planets around other stars. But with the James Webb Space Telescope's 6.5m mirror not launching until 2018, we won't be seeing alien cities for quite some time.

PHOTO: SCIENCE PHOTO LIBRARY, SUPERSTOCK, CORBIS

"Forget finding Earth's twin and concentrate on searching for Earth's cousin"

Professor Sara Seager, one of the world's leading authorities on exoplanets at MIT

[redacted]

in an Earth-sized orbit. "It is sitting in Kepler's data set," she says. "We haven't found it yet because we haven't completed the analysis."

Ideally, the E-ELT and TMT would be used to analyse the light given off by the many planets being detected by Kepler to see if there are any signs of oceans, land and life. But there's a catch. Kepler was set up to study a dense star field, so its designers could be confident of it spotting lots of exoplanets – its gaze is fixed 600 to 3,000 light-years from Earth. The E-ELT and TMT, on the other hand, will be peering much closer to home. The E-ELT, for instance, will only be able to characterise the atmospheres of planets that are up to 30 light-years away. So rather than analysing Kepler's many finds, both ground-based super 'scopes will have to concentrate their hunts for Earth's twin using much closer stars and that will be tricky because the nearer we look to Earth, the fewer Sun-like stars there are.

But the E-ELT and TMT aren't our only hope. Space telescopes can also characterise exoplanets. These can see further because they are beyond the blurring effects of Earth's atmosphere. Launching in 2018, the James Webb Space Telescope, NASA's replacement for the Hubble and Spitzer space telescopes, will be a prime instrument for analysing the atmospheres of rocky planets.

Beyond that, there are a number of space-based missions that, unlike the James Webb telescope, will be purpose-built to study exoplanet atmospheres. The Exoplanet Characterisation Observatory (EChO), a space telescope operating in the optical to infrared wavelengths, is currently being studied by the European Space Agency for a possible launch in 2024.

However, the ultimate mission to find Earth's twin is one NASA calls the Terrestrial Planet Finder (TPF), and ESA calls Darwin. Both imagine flotillas of space telescopes working together to collect the light from nearby rocky exoplanets to look for biomarkers. The space agencies worked together on the concepts before dropping them when the budgets began to rise above €1.5 billion (£1.1 billion). Where EChO would require a planet to pass in front of its parent star to measure its atmosphere, TPF would directly image a planet's atmosphere.

Although removed from the official programmes, they have not been forgotten by the scientists. "We've not given up hope on TPF," says Seager. She points to a number of developments, specifically the miniaturisation of satellites and the rise of the commercial launch companies that aim to drive down the cost of getting into orbit. "I think in five years we will be able to revisit the concept of TPF," she says.

LIFE SIGNS

But perhaps the most exciting element of our hunt for Earth's twin is the prospect of finding life on another planet and Seager has a way to increase our chances of discovering it. "Forget finding Earth's twin for the moment and concentrate on searching for Earth's cousin," she says.

As more and more theoreticians have been investigating planetary habitability, so they are beginning to think that it may be achievable on planets other than exact replicas of Earth. They had thought that there was a single 'Goldilocks zone' around each star where a planet's temperature would be not too hot and not too cold. This assumed that habitable exoplanets would have atmospheres just like Earth.

But recently, the researchers have been looking at the consequences of a planet having more hydrogen in its atmosphere than Earth. Such a concoction would be entirely possible for a super-Earth – a planet larger than our own but smaller than a gas giant – because the larger world would generate a greater pull of gravity to hold on to the flighty gas. The hydrogen would produce a powerful greenhouse effect and keep the planet warm. So, the habitable zone for a super-Earth would be further from the parent star than for an Earth analogue.

There is also the temperature of the stars to consider. Many exoplanets have been discovered orbiting red dwarf stars that are cooler than the Sun by

FOR and AGAINST: Will we spot signs of life on another planet within the next 25 years?

⊕

Dr Joe Liske
European Southern Observatory, Garching, Germany

"We will need a bit of luck to find an Earth-like planet close enough for the E-ELT to observe, but if there is a suitable rocky planet nearby, I think it will have life. Life emerged on Earth so rapidly after conditions allowed it to that it makes me think it is an efficient process. So, whenever the conditions are vaguely right, life will start. The E-ELT has the potential to give us the first signs of extraterrestrial life."

⊖

Dr Dave Spiegel
Princeton University, New Jersey, US

"I'm not sure it will be within 25 years. The early appearance of life on Earth is not that strong a piece of evidence for life's abundance. It's hard to draw a conclusion from a sample of one. We have to look at other Earth-sized planets, but I don't think the first generation of instruments that do this will be sensitive enough to definitively determine whether they host life. It's a really hard observation to make."

[redacted]

798 hexagonal mirrors,
each 1.4m in size, will make up the 39m-wide primary mirror on the European Extremely Large Telescope

7 telescopes
are already located on the Cerro Armazones mountain, Chile, which will be home to the European Extremely Large Telescope. Unlike the others, the E-ELT will be at the summit.

777 confirmed sightings
of exoplanets were listed by The Extrasolar Planets Encyclopedia, as of 23 August 2012. The number changes every time a planetary discovery is confirmed in a scientific journal.

thousands of degrees. This puts their habitable zones much closer to their fiery surfaces. Again, we need to find closer examples to Earth for the E-ELT and TMT to analyse, but red dwarf stars are far more common in our Galaxy than Sun-like stars, so the odds of finding something nearby is higher.

ONE GIANT LEAP

Yet as tempting as it will be to think about visiting a habitable world (see 'Living on Earth's twin', right), the laws of physics seem stacked against us – even when it's a planet that's relatively close. Take Gliese 667C, one of the nearest stars thought to have a rocky planet in its orbit. At 22 light-years, or 129 trillion miles, it would take millennia to reach with current rocket technology.

So, rather than going there to determine if there really is life, astronomers will almost inevitably have to develop better and better instruments to check their findings from afar. The prospects of discovering signs of life on an exoplanet in the next few decades are good so long as we think widely about what could make a planet habitable. But finding a twin world to Earth that's near enough to analyse may take longer.

"Exoplanet researchers are on a high all the time," says Seager. "We all want the next big discovery." And that next big discovery will be a habitable world. ■

DR STUART CLARK is an astronomy author with a PhD in astrophysics

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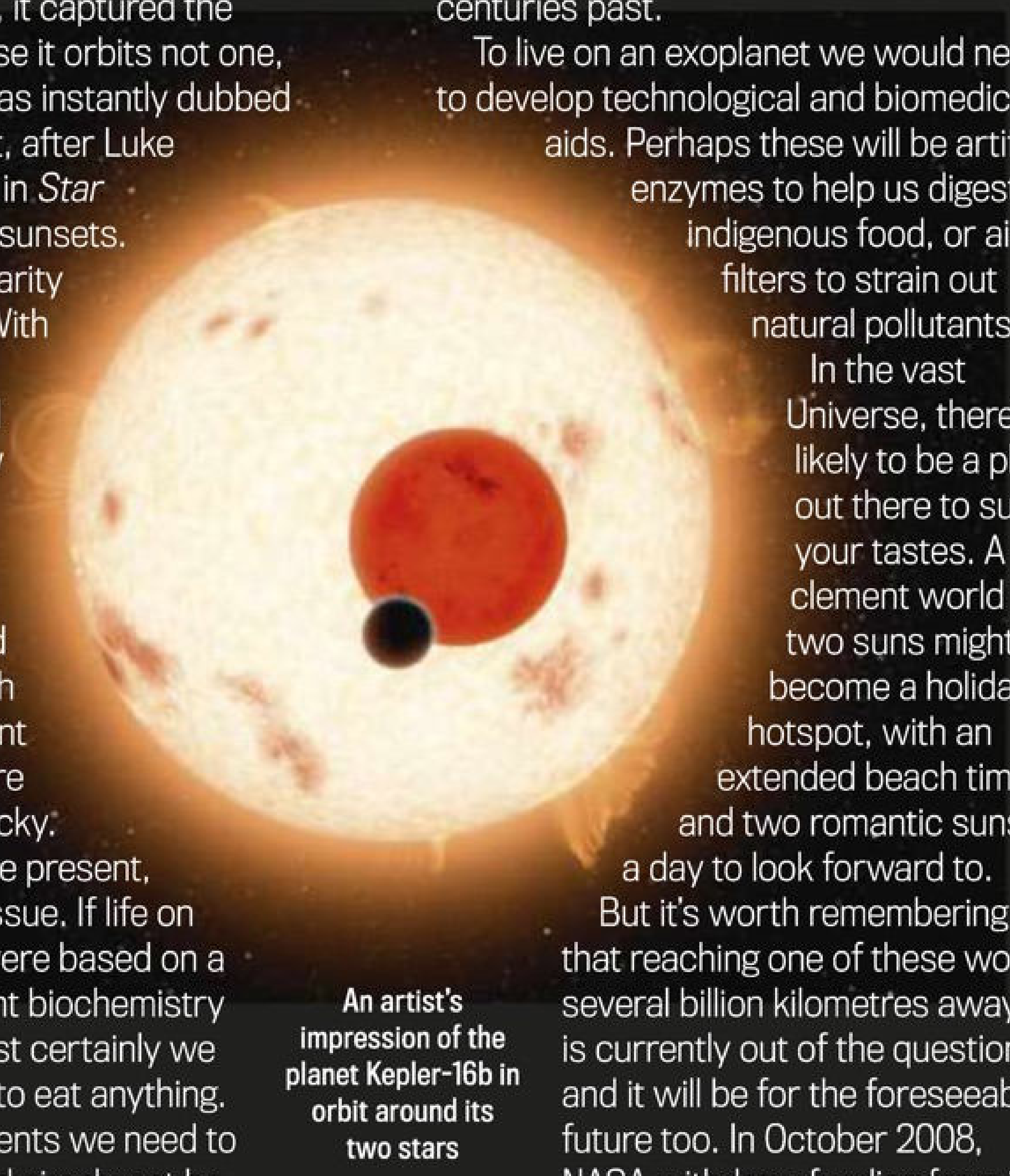
http://kepler.nasa.gov/
Official Kepler space telescope website, providing information on the latest exoplanet discoveries

The alien view of twin suns from the surface of a moon around the planet Kepler-16b

LIVING ON EARTH'S TWIN

Would our planet's doppelgänger be an easy place to set up home?



An artist's impression of the planet Kepler-16b in orbit around its two stars

Even though it is proving difficult to develop another expedition to the Moon, the temptation to wonder about life on an exotic exoplanet is just too great to ignore.

When the planet Kepler-16b was discovered in 2011, it captured the imagination because it orbits not one, but two stars. It was instantly dubbed the Tatooine planet, after Luke Skywalker's home in *Star Wars* with its twin sunsets. However, the similarity would end there. With a temperature of -70°C, it would feel more like the snow planet Hoth from *The Empire Strikes Back*.

Even if we found a twin of Earth with rather more clement weather, living there might still prove tricky. While water may be present, food might be an issue. If life on this other planet were based on a completely different biochemistry to ours, then almost certainly we would not be able to eat anything. The chemical nutrients we need to keep us alive would simply not be present. Colonists would have to grow their own food.

Even if life is the same throughout the Galaxy, other dangers may still lurk. Microbes on Earth's twin could be deadly to us because we have evolved no natural defence against them. It would be comparable to the way that Western diseases cut down swathes of indigenous people during the European explorations in centuries past.

To live on an exoplanet we would need to develop technological and biomedical aids. Perhaps these will be artificial enzymes to help us digest indigenous food, or air filters to strain out natural pollutants.

In the vast Universe, there's likely to be a planet out there to suit your tastes. A clement world with two suns might become a holiday hotspot, with an extended beach time and two romantic sunsets a day to look forward to.

But it's worth remembering that reaching one of these worlds several billion kilometres away is currently out of the question – and it will be for the foreseeable future too. In October 2008, NASA withdrew funding from its Breakthrough Propulsion Physics group because, despite 16 peer-reviewed papers, no warp drive breakthrough could be envisioned to get us there in anything like a reasonable time.

PHOTO: SCIENCE PHOTO LIBRARY, NASA

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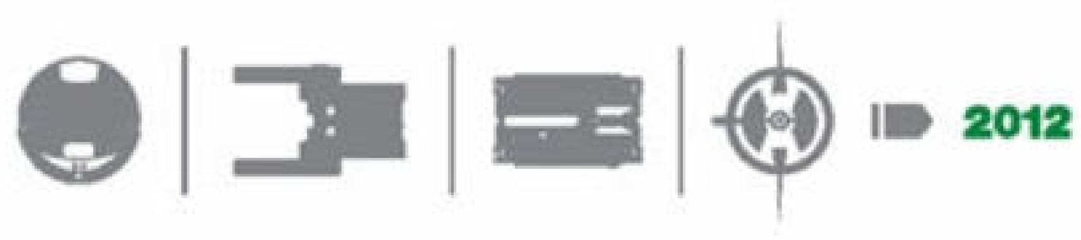

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RISE OF THE BIO

Some of evolution's finest designs are being mimicked to build robots with incredible abilities. **Duncan Graham-Rowe** takes a close look at the machines that can climb vertical walls, sprint and eat raw sewage...

SAY THE WORD 'robot' and it's hard not to think of shiny, mechanical droids, rolling around busily beeping and whirring like R2-D2. But the fact is, if robots are ever to stand a chance of becoming a major part of our world, they are going to have to first lose the dustbin-on-wheels image and take on something altogether more organic.

After decades of being ingrained into our psyche, the classic mechanical notion of how robots should look, move and function is now undergoing a radical transformation as roboticists – from universities and private companies alike – are increasingly taking inspiration from the animal kingdom. After all, why try to engineer solutions to problems that Nature has already spent millions of years of trial-and-error perfecting?

So, out goes the wheel, the gear and the battery pack, to be replaced by leg, muscle and stomach. This transformation is giving rise to a new class of robot that is faster, more agile and dexterous, and ultimately better equipped to cope with life among us. These 'biobots' could even end up sitting down to dine with us.

But the real prize is the growing hope and belief that mimicking biological systems could dramatically accelerate the quest for true artificial intelligence. By interacting with the world like humans, robots will finally start to think like us. Here we take a look at five pioneering biobots that are leading the charge in this merging of biology and robotics.

PHOTO: PATRICK KNAB

>BASED ON
HUMAN BEING

ECCEROBOT

The robot with muscles, bones and tendons... and the ability to learn

IF YOU WERE to remove someone's skin, as though creating a Gunther von Hagens exhibit, what you'd be left with is something resembling Eccerobot. While most androids are made of conventional mechanical joints and precision motors covered with a rubbery skin-like coating to make them look human, Eccerobot's human-like qualities are more than skin deep.

"Eccerobot has a torso and arms made up of bone-like pieces – many copied from *Gray's Anatomy*," says Prof Owen Holland, a roboticist at the University of Sussex who is a lead investigator on the project. "These bones are held together and moved by soft tissues in the form of rubber bungees connected by cords to the spindles of electric motors." Winding or unwinding the cords stretches or relaxes the bungees, just as we stretch or relax our muscles. These artificial muscles then pull on the thermoplastic bones to create movement.

The result is movements that have a human quality about them, says Holland. "When a traditional robot moves a joint, it has no effect on the rest of its body," he says. This is why they move in such a characteristically stiff 'robotic' fashion. But with Eccerobot (Embodied Cognition in a Compliantly Engineered Robot to give him his full name), whenever part of him moves, the movement is distributed throughout the whole body.

The consortium of robot labs across Europe that developed Eccerobot is currently looking at how this sort of musculoskeletal robot could be used in manufacturing. It is also creating a boy-sized version of Eccerobot, called Roboy, who unlike his older sibling, will have legs and the ability to walk. The hope is to have a prototype strutting around by March 2013.

MIND AND BODY

One of the main motivations behind Eccerobot's development was to explore the link between movement and cognitive ability. By combining data from sensors across the robot's body with information from his camera, or 'eye', he can learn how movements in one part of his body will affect another and what interactions with the outside world, such as grasping a coffee cup, 'feel' like. This is a form of low-level intelligence, says Professor Rolf Pfeifer, director of the University of Zurich's Artificial Intelligence Laboratory and another of the lead investigators on the project.

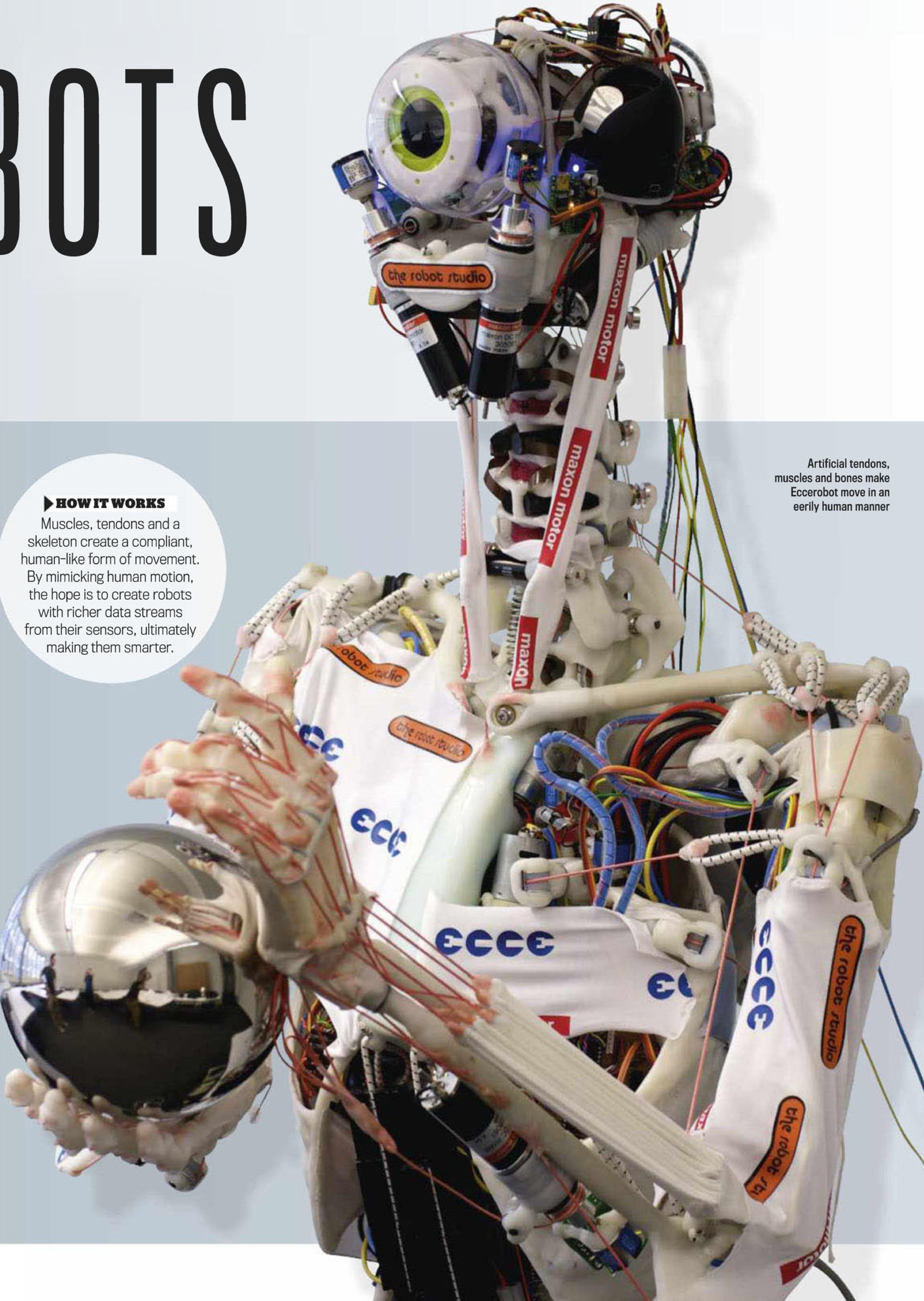
"There is a tight connection between sensory-motor processes and cognition, thinking and intelligence," says Pfeifer.

For a robot butler to be of any real use, it would need to be able to respond to different situations and interact with its environment. Eccerobot provides the first clues as to how that could be achieved.

BOTS

HOW IT WORKS

Muscles, tendons and a skeleton create a compliant, human-like form of movement. By mimicking human motion, the hope is to create robots with richer data streams from their sensors, ultimately making them smarter.



Artificial tendons, muscles and bones make Eccerobot move in an eerily human manner

BASED ON
BIG CAT

CHEETAH

The sprinting 'bot that's the fastest mechanical thing on four legs

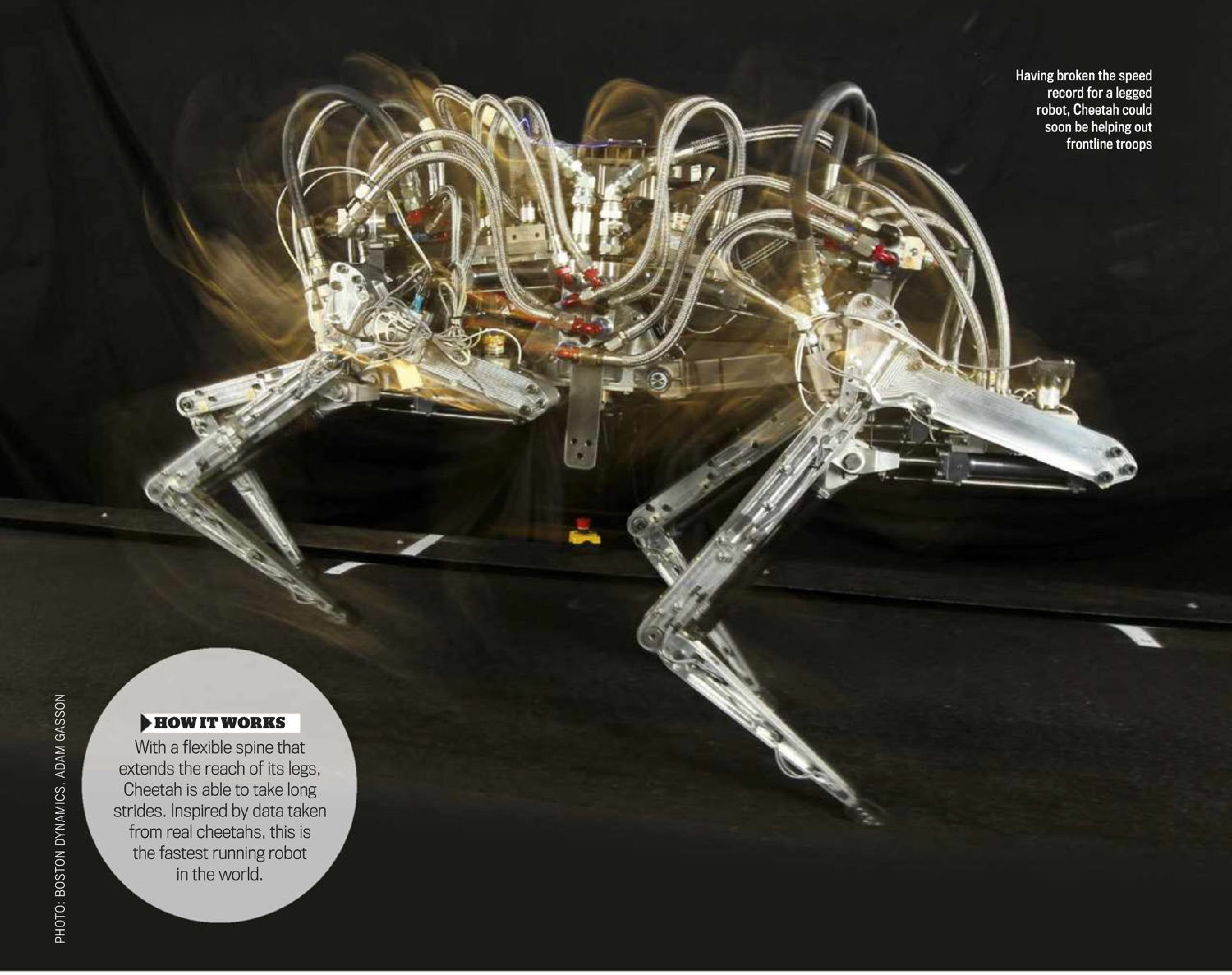
IF YOU WANT to build a robot that can run fast, what better to model it on than the cheetah – the fastest land animal. That's precisely what US robotics firm Boston Dynamics has done, creating a four-legged sprinting 'bot that is anatomically inspired by its namesake. With the help of Professor Alan Wilson, an expert in fast-moving mammals at the Royal Veterinarian College, London, the company identified traits that enable cheetahs to reach such high speeds.

Boston Dynamics, founded by former MIT professor Dr Marc Raibert, had a YouTube hit with one of its creations, Big Dog, a four-legged robot mule that has the ability to stay upright even when given a hard shove from the side. But the Cheetah 'bot is all about speed. "We noticed that the cheetah's back flexes and unflexes, allowing it to increase its stride length without having longer legs," says Raibert.

A cheetah's back is so flexible that it enables its hind feet to be thrust underneath its chin when it sprints. This means its feet are on the ground for longer, allowing them to support more weight – a crucial factor dictating maximum running speed. "So we designed the Cheetah robot to have an articulated back," says Raibert. Cheetah 'bot also maintains a form of dynamic stability that many creatures use when running, where the body is effectively in a continual state of falling forwards.

Earlier this year, the Cheetah 'bot broke the world speed record for a legged robot, thrashing along a treadmill at 29km/h (18mph) and smashing the previous record of 21km/h (13mph) set over 20 years ago. The target is about 48km/h (30mph) and just as *Focus* went to press the Cheetah 'bot broke its own record, hitting 45km/h (28mph). This could lead to a future of fleet-footed robots delivering supplies to front-line troops, or carrying medication into an earthquake zone. But before doing this, Cheetah needs to stand on its own four legs. It currently runs with a support boom holding it in place, while its power is supplied through a cable.

Cheetah is being developed so it has on-board power and a more advanced control system.



Having broken the speed record for a legged robot, Cheetah could soon be helping out frontline troops

HOW IT WORKS

With a flexible spine that extends the reach of its legs, Cheetah is able to take long strides. Inspired by data taken from real cheetahs, this is the fastest running robot in the world.

PHOTO: BOSTON DYNAMICS, ADAM GASSON

BASED ON
COW'S STOMACH

ECOBOT III

A robot with real guts, which it can use to digest almost anything

RATHER THAN A plug socket, EcoBot III's energy comes from a diet of dead flies, prawn shells, rotten fruit and even neat urine that it digests in its stomach. It then uses the power it has created to trundle around.

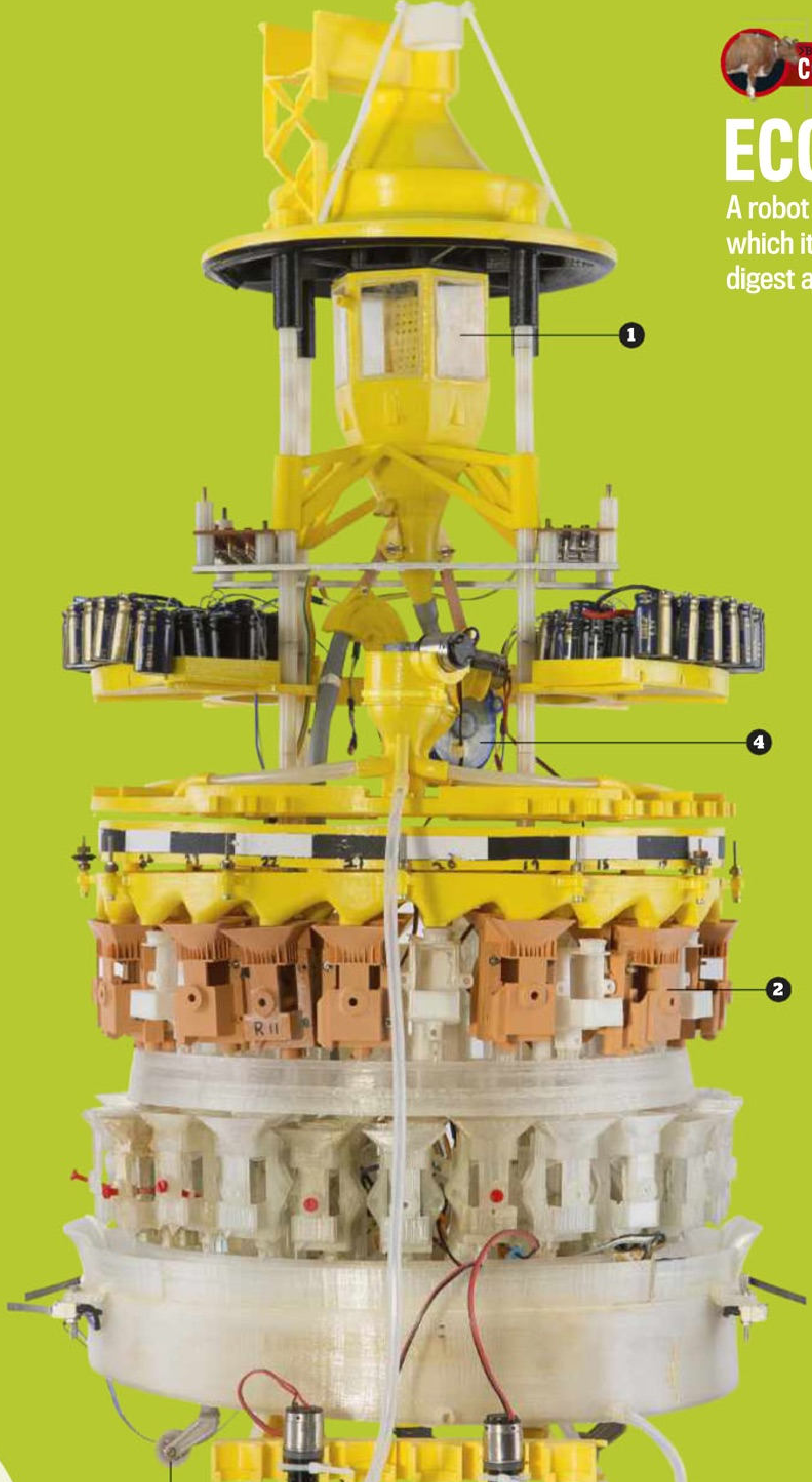
With its wheels and classic droid-like appearance, at first glance there's nothing particularly biological about EcoBot. But then the smell hits you. Containing 48 microbial fuel cells, this robot may have personal hygiene issues, but it is blazing a trail for self-powered robots. Even NASA has taken an interest in using microbes to power robots.

FULL STOMACH

EcoBot III has been developed at Bristol Robotics Laboratory, a joint venture between the University of Bristol and the University of the West of England. Each of its fuel cells – its cow-like stomachs – contain a culture of hungry bacteria that happily feed on organic matter. In the resulting reaction, electrons are released which then drive an electrical circuit that powers the robot. By giving the robot the intelligence to feed itself through a dispenser, EcoBot III was able to survive for up to seven days autonomously.

But rather than looking to create an army of flesh-eating 'bots bent on world domination, the Bristol lab's aim is to develop robots that can happily graze on the organic matter around them – and our waste products – and use the resulting energy to get around, monitoring the environment.

An inevitable consequence of a digestive system is that EcoBot III eventually has to dump its waste somewhere. So in the lab at least, it has its own litter tray.



1. FEEDING
The robot first dines on its diet of sewage water, dead flies or other forms of 'food', which it accesses via a dispenser. This food passes into 48 separate anaerobic digestion chambers.

2. DIGESTION
Bacteria in the anode chambers of the microbial fuel cells (MFCs) feed on the organic matter, metabolising it. Chemical reactions take place that cause hydrogen protons and electrons to be given off. The microbes, which are embedded within the surface of the carbon anode, pass electrons to it. The electrons then flow through a circuit to a cathode in a separate chamber, creating an electrical current in the process.

At the same time, the hydrogen protons pass into the cathode chamber that contains water. Here, oxygen dissolved in the water combines with the hydrogen protons and hydrogen electrons to produce more water, a by-product of the MSC that is given off as steam.

3. LOCOMOTION
The electricity from each MFC is used to power the robot, enabling it to move about on wheels and feed again when it gets hungry.

4. WASTE DISPOSAL
EcoBot creates its own waste matter. This is processed in the waste evacuation pump, a peristaltic mechanism contained in a blue housing that mimics the movement of the intestines.

HOW IT WORKS
Microbes in a series of cow-like stomachs break down food, producing electricity that powers EcoBot III. It is then able to move around to find its next supply of junk food.

BASED ON
HUMAN HAND

BIOTAC

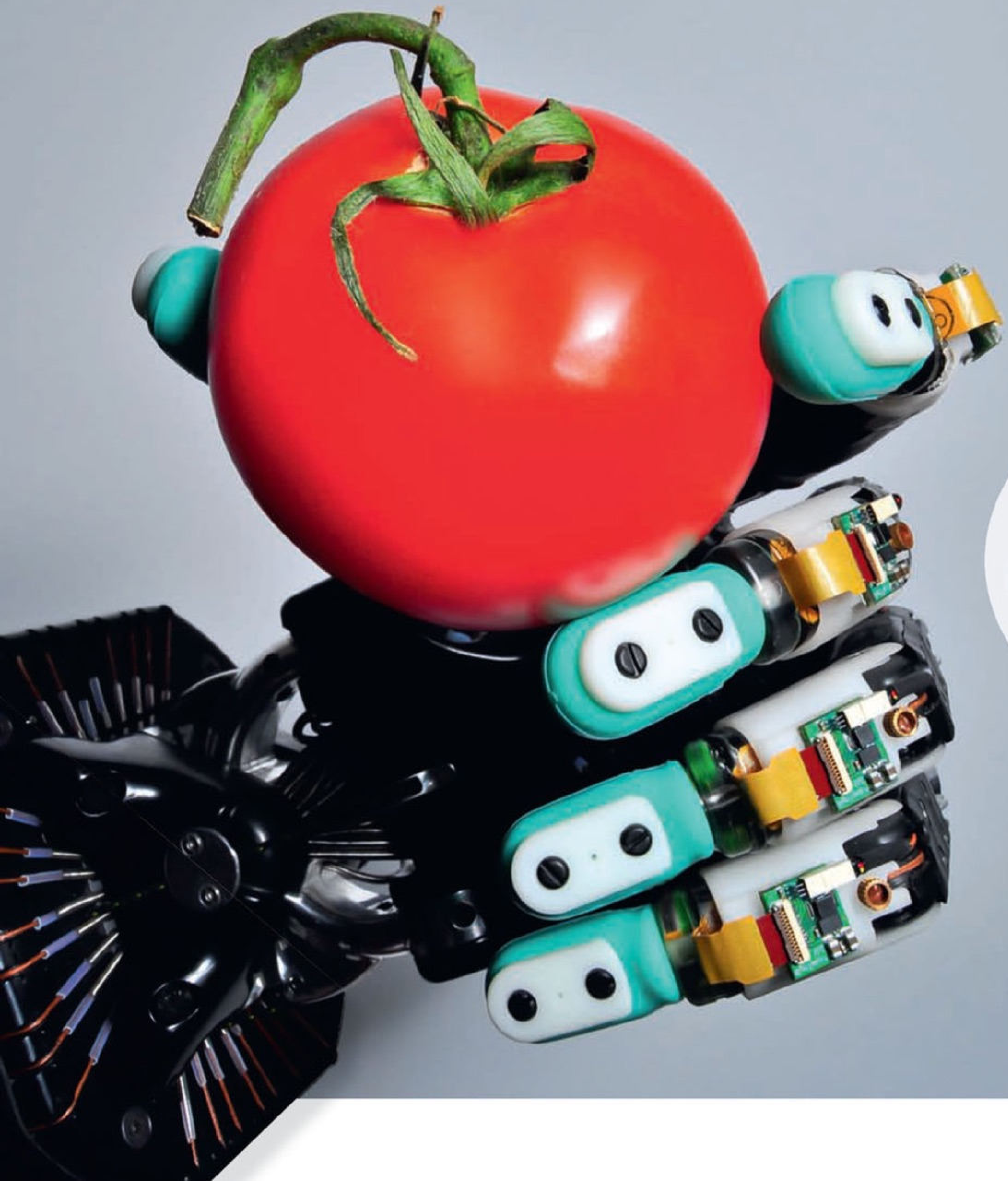
An artificial fingertip with a better sense of touch than ours

THE FINGERBOT, OR BioTac to give it its official name, has artificial bone, skin and even fingerprints to mimic, and even improve upon, our sense of touch. Despite the speed and efficiency with which the $20 billion (£13 billion) a year industrial robotics sector can manipulate objects, these robots essentially do so blindly with no real sense of touch, says Professor Gerald Loeb, an expert in biomimetics at the University of Southern California, where BioTac has been developed.

The disembodied finger, developed by Loeb and post-graduate colleague Dr Jeremy Fishel, largely mimics the human finger. "The trick is not to blindly copy but to extract principles of operation and adapt them," says Loeb. The results are impressive. BioTac can correctly identify materials 95 per cent of the time and distinguish items that human volunteers were unable to using their sense of touch alone.

BioTac's elastic skin is separated from a bone-like plastic by a liquid filling, much the same as in our fingers. As the artificial finger slides over a surface, the skin vibrates in characteristic ways and these vibrations are picked up by a hydrophone within the bone. A fingerprint and fingernail enhance and relay the vibrations. The vibrations are analysed by algorithms designed to capture the thought processes humans use when characterising the texture of surfaces. Other types of sensor, which can detect heat and pressure, aid the identification process. Fortunately for BioTac, the only sensation it's incapable of experiencing is pain.

Loeb and Fishel are partners in a company called SynTouch and are selling BioTac sensors to the manufacturers of industrial robots and prosthetic hands.



HOW IT WORKS

The internal structure of a human finger is replicated in a robotic digit. It can sense what it is touching from the vibrations generated as it passes over a surface.

Machines get touchy feely: a robotic hand incorporating the BioTac finger tips

>BASED ON
GECKO

TBCP-II

This tiny tank has the ability to scale vertical walls

CREATING A ROBOT that can climb walls has obvious benefits. Imagine it climbing a skyscraper to clean its glass or silently negotiating its way through a dangerous building in a war zone. But achieving this goal has been fraught with difficulty.

If the adhesive the robot uses is wet, it will leave a trail. So a dry adhesive is a must. Suction could be used, but it requires a large amount of energy and magnets would limit climbing antics to metals. So researchers at Simon Fraser University in Canada have taken inspiration from a real-life wall crawler, the gecko.

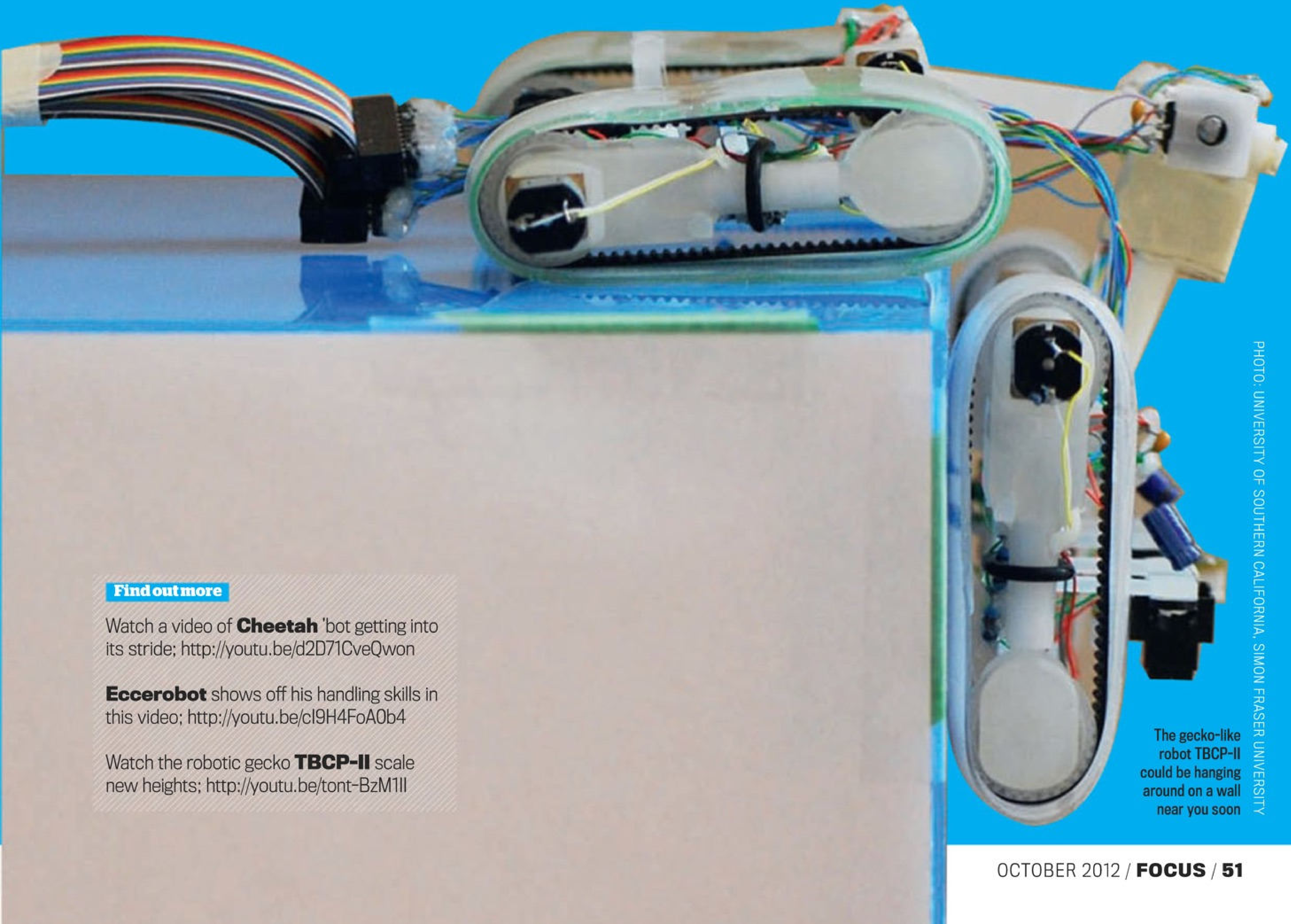
Their gecko 'bot, named TBCP-II, looks nothing like a gecko, having two pairs of tank-like treads to get about. But what it does have is gecko-like hairs on these treads called setae. In a gecko, these setae are themselves covered with tiny structures called spatulae. Molecules on the surface of these are attracted to molecules in the surface of the structure that's being climbed by Van der Waals force – the attractive force between molecules. While the force generated by each spatulae isn't strong, there are so many they can hold geckos to a wall.

The team created artificial setae that generate sufficient force to make gecko 'bot stick. An articulated spine also allows it to negotiate transfers around corners and from wall to ceiling. ■

HOW IT WORKS

Coating the robot's tank tracks with microscopic hair-like structures called setae makes it possible to mimic the way geckos can stick to, and move about on, walls and ceilings.

DUNCAN GRAHAM-ROWE is a science and technology journalist



Find out more

Watch a video of **Cheetah** 'bot getting into its stride; http://youtu.be/d2D71CveQwon

Eccerobot shows off his handling skills in this video; http://youtu.be/cI9H4FoA0b4

Watch the robotic gecko **TBCP-II** scale new heights; http://youtu.be/tont-BzM1II

The gecko-like robot TBCP-II could be hanging around on a wall near you soon

PHOTO: UNIVERSITY OF SOUTHERN CALIFORNIA, SIMON FRASER UNIVERSITY

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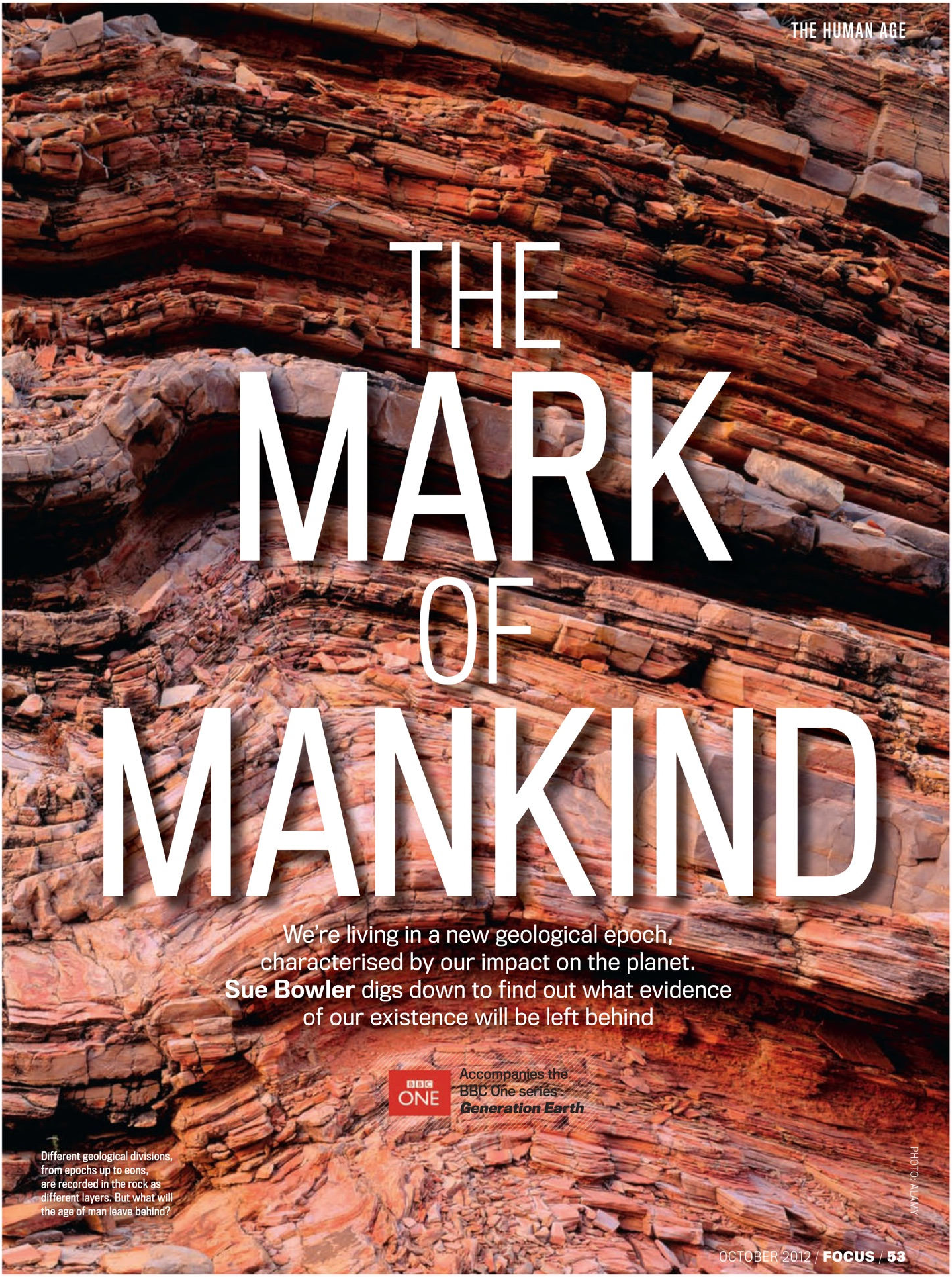


THE MARK OF MANKIND

We're living in a new geological epoch, characterised by our impact on the planet. **Sue Bowler** digs down to find out what evidence of our existence will be left behind

Accompanies the BBC One series ***Generation Earth***

Different geological divisions, from epochs up to eons, are recorded in the rock as different layers. But what will the age of man leave behind?

PHOTO: ALAMY

STROLLING ALONG London's South Bank, the monumental stone buildings of Westminster, concrete bulk of the National Theatre and distant skyscrapers of Canary Wharf feel like an enduring testament to human achievement. Over the last century, mankind has transformed the surface of the planet, changes celebrated in the upcoming BBC series, *Generation Earth*.

Our activities are having an impact so lasting that they define a new geological epoch: the Anthropocene – the 'age of man'. Like other geological eras, evidence for the Anthropocene will be left in layers of rock. But what, exactly, would be left behind if mankind were to suddenly die out and an alien geologist examined our planet in the far future? Would it be remnants of our towns and cities? Or less tangible changes to Earth's atmosphere, oceans and biosphere? The answer might surprise you. "Not all of these features will be present in the future geological record," says Dr Jan Zalasiewicz of the University of Leicester.

Earth without mankind is hard to imagine, although it's possible we might leave to colonise other planets and moons, or simply go extinct. There have already been five mass extinctions in the history of the Earth. If the asteroid impact that killed the dinosaurs happened today, for instance, the dust kicked up from the catastrophic collision would block out sunlight long enough to bring about worldwide crop failure.

So what would happen then? Our current infrastructure of roads and cities certainly looks solid, but they also require maintenance. Take away the people and fast-forward 500 years, and London will be wearing away: the embankments that confine the Thames will fail in a few centuries – water will flood the sewers and Underground network, eroding the foundations of the buildings above. If you also consider rising sea levels and the corrosive effects of rainwater, then modern buildings are more vulnerable than the Pyramids at Giza. Within tens of thousands of years, our government offices and gleaming financial districts will have collapsed into landscapes of rubble.

> **"In terms of magnitude, we're not living in a mass extinction – we're not even close"**
>
> Professor Charles Marshall, a palaeobiologist at the University of California, Berkeley

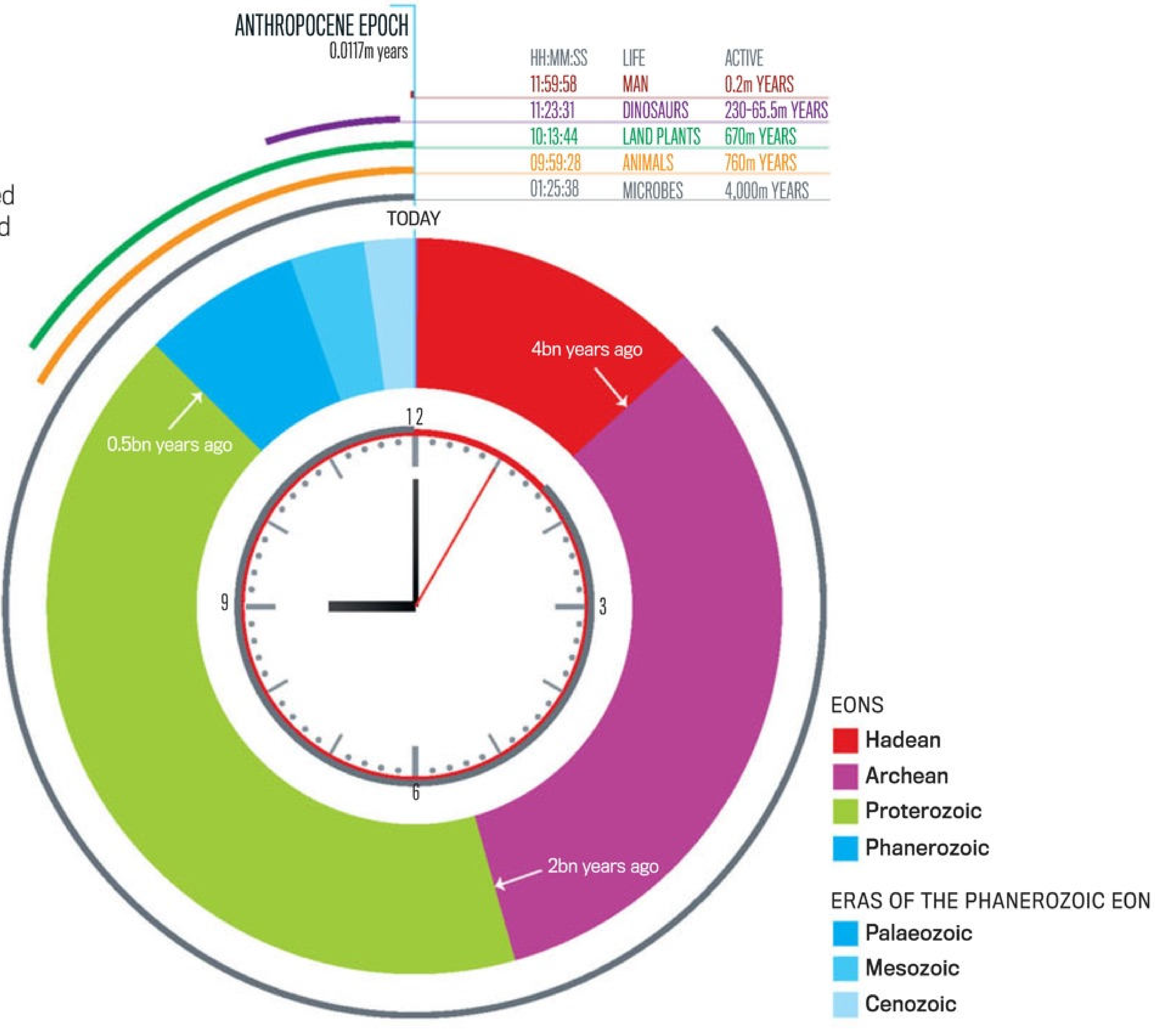
But mankind has done more than build cities. We've also changed the chemistry of the oceans and the atmosphere by burning fossil fuels, exploiting nuclear energy and manufacturing materials. We've shaped the landscape, moving three times more sediment than rivers. We domesticated animals and cultivated plants, replaced forests with farmland and have become the world's top predator, limiting biodiversity on land and sea. But which of these changes will be recorded in the rocks?

ROCK BANDS

Geologists deduce the relative ages of rocks from observations in the field, starting with the fact that younger sedimentary rocks form on top of older ones. Identifying younger and older layers – often using fossils – leads to a local sequence of geological layers that can be compared with others to build up a worldwide timescale. ➔

THE HISTORY OF THE EARTH IN 12 HOURS

If the history of our planet were condensed into a 12-hour period, *Homo sapiens* would appear in the last two seconds and the Anthropocene epoch, when mankind starts leaving a mark in the geological record, would begin around one-tenth of a second ago



HH:MM:SS	LIFE	ACTIVE
11:59:58	MAN	0.2m YEARS
11:23:31	DINOSAURS	230-65.5m YEARS
10:13:44	LAND PLANTS	670m YEARS
09:59:28	ANIMALS	760m YEARS
01:25:38	MICROBES	4,000m YEARS

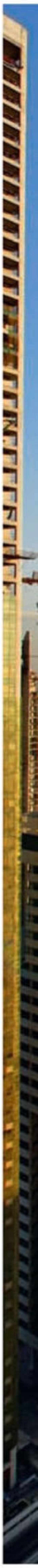


PHOTO: SUPERSTOCK

The rare elements found in a city like Dubai could mean that it becomes an ore mine in the far future

BUILT TO LAST?

CITIES

WHETHER TRACES OF cities survive depends largely on their location. Those in regions that are continually subsiding – like New Orleans, which lies on a river delta – have quite a good chance of making it into the geological record. Oslo, which is on land that's been rising since the last Ice Age, does not. Bigger is better too, with megacities such as Tokyo leaving larger marks. Conglomerates of rock resulting from generations of building over past foundations will also influence what remains. For example, 2,000 years of habitation has left an 8m-thick sediment under the city of York.

The concentration of rare elements would be found in urban areas. Gold, silver and platinum are concentrated in places such as the jewellery shops of Bond Street, London, while our electronic devices use even more exotic elements. In the future, cities may be exploited as ore deposits.

Significant environmental changes are marked by unusual layers or abrupt alterations in the nature of the sediments. The branch of geology that studies layers is known as stratigraphy. "Stratigraphic changes happen when the world changes comparatively fast," says Zalasiewicz.

Where a change appears simultaneously worldwide, it becomes a boundary. The boundary between the Cretaceous and Palaeogene periods, for example, is a thin band of rock unusually rich in the element iridium, which is thought to come from that cataclysmic asteroid impact 65 million years ago. Stratigraphers like Zalasiewicz say that such records in the rock can be used to work out what happened before and after a boundary. "We think that it can be done for the Anthropocene, on the basis of recent sediments laid down over decades and centuries."

And there's one clear candidate for a global mark of mankind: the testing of atomic bombs in the 1950s. The radioactive fallout arising from these explosions originated in a narrow time period and quickly spread worldwide, generating long-lived radioactive signatures that, like the iridium anomaly, would create a distinctive boundary.

But if the Anthropocene is characterised by changes that humans have made to the environment, then our geological epoch started even earlier. This was the finding of geochemist Christopher Vane of the British Geological Survey, whose team sampled the estuaries of rivers such as the Clyde and Thames. He found polymers that indicate the burning of coal and petrol, plus manufactured compounds like flame retardants and chlorinated chemicals used in electronics. These compounds, recorded in the mud over two centuries, reveal the Industrial Revolution.

But while the growth of industry produces new materials that could endure in the long-term, it doesn't happen in every society at the same time. Stratigraphers call such changes 'diachronous' – they occur at different times in different places. Industrialisation offers a strong signal of the Anthropocene, but it's inconsistent.

Urbanisation accompanies industrialisation, but few recognisable features of our cities will last. Seafloor sediments survive much better than those on land – two-thirds of Britain's

Q&A: DALLAS CAMPBELL

The presenter of the new BBC series *Generation Earth* on filming the world's grandest structures

What is the series about?
We concentrated on how human beings have changed the planet, divided into three parts. Part one is about the history of the skyscraper and the infrastructure that surrounds cities – drainage and everything else. Part two is about transport – the history of aviation and how people commute, through to space travel. Then part three is looking at food and fuel.

So the series is all about engineering?
Human beings have become, as a species, a force of nature in their own right. We don't adapt to suit our environments, we have the engineering skill to change environments to suit us. The series is celebrating the scale and speed of what we've been able to achieve in an incredibly short time, within the last 100 years or so. It's a global story so we've travelled around a lot.

Which engineering feat impressed you most?
The new drainage system in Mexico City, which they're building because the city is sinking. It sounds boring, but that's the whole point of infrastructure. Invisible structures that make life bearable in cities and keep the whole show running are actually fascinating. And they take on cathedral-like qualities in terms of scale – these great pipes and chambers designed for human waste that no-one is ever going to see.

Was filming a challenge?
Yes, absolutely. In this series we take the audience to places they've never seen before. The stuff we shot on the Burj Khalifa in Dubai, the world's highest building, has been the highlight for me. When you go to tall buildings, like the top of the Empire State Building, they always have a viewing platform where you sit and take photos – the things we've filmed have been *above* that.

What do you hope mankind will leave behind?
It's very hard to imagine too far into the future. We don't have infinite resources or real estate, and we're not in a position to jump onto space ships. If humans left the planet now and the Earth was left to decay, I think it's going to be the infrastructure that survives. The London Underground system, built by the Victorians, will outlive us all.

In millions of years the many roads of the world's megacities will be reduced to carbon-rich seams of sediment at the bottom of the ocean

PHOTO: GETTY, THINKSTOCK X4

BUILT TO LAST?

TRANSPORT

EXCAVATIONS AND EARTHWORKS are required to build modern ports, road and rail systems. These currently stand out in the landscape because they're linear – highways and tunnels through mountains, for instance – but they're unlikely to survive long-term. Even the hydrocarbon products used for surfacing roads will eventually erode to become seams of carbon-rich sediment under the sea. And while motorways and airports use a lot of concrete, this is held together by calcium minerals that dissolve in acidic rain to produce calcium-rich water.

Stalactites and stalagmites in caves are made of calcium carbonate from mineral-rich water; a 1m-long stalactite can gain half a cubic metre of limestone in a million years. Growth is faster with a warmer climate and more minerals dissolved in rainwater, so a greenhouse world with more concrete will create impressive-looking caves.

HOW LONG WILL IT LAST?

The lifespan of man-made objects*

Drink can: 100 years
Soft drink aluminium cans aren't very reactive, food tin cans decay faster

Linen shirt: 35,000 years
Natural fibres usually decay quickly, but linen can survive much longer

Glass bottle: 1 million years
Silicon dioxide, a component of rocks like granite, is very stable

Polystyrene cup: indefinitely?
Polystyrene fractures easily, but isn't degraded by microbes

*Approximate life spans reflect being buried in a landfill site rather than being left in the environment as litter

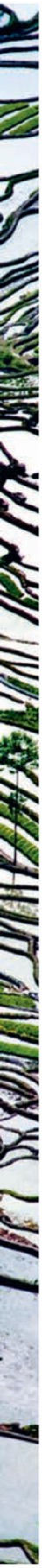
BUILT TO LAST?

FOOD

AGRICULTURE HAS CHANGED the landscape over large areas, replacing a vast variety of plants and animals with farm crops. But most farm animals would die without farmers and predators would thrive on domesticated prey. Such a small proportion of creatures would survive as fossils that this is unlikely to show in the geological record.

However, crops spread pollen that reaches marine sediments, while artificial fertilisers change the sediments that form at ocean margins. Fertilisers contain nitrogen and, when washed into the oceans, they feed microscopic plants. The resulting algal blooms take up undersea oxygen, killing other forms of marine life. These 'dead zones' may remain in the record as carbon-rich black shales – potential sources of hydrocarbon deposits in the far future. Nitrogen from manufactured fertilisers can be identified because it contains a distinctive proportion of isotopes – elements with different numbers of neutrons in the atomic nucleus. It would leave an isotopic fingerprint of farming that's been detected within deposits in Canadian Arctic lakes.

Humans have made an obvious mark on the landscape with agriculture, like these paddy fields in China



sedimentary rocks formed under the sea – so cities need to be located in subsiding regions for their debris to withstand the effects of erosion from rain.

Rare metals such as lithium, mined and concentrated for use in electronics, will be carried away by rivers and become an unusual feature of marine sediments. City rubble will produce strange sedimentary rocks that would be made from fragments of the exotic polished materials that decorate our prestigious buildings.

On top of this, massive structures will leave their mark in undersea sediments. Creatures living in soft sediment churn up surface layers to produce fossil features known as bioturbations. According to Zalasiewicz, our industrial infrastructure will create something similar but on a huge scale – what he calls 'megabioturbations'. "Fossilised subways and foundations will be distinctive – anyone in the future who looks at strata as we do will see a difference," he says.

Future geologists might also discover fossilised rubbish. While an object itself might decay relatively quickly, (see 'How long will it last?', p57) it could leave an impression in the surrounding sediment that preserves its shape. Bottles, coke cans and even MP3 players would look a little like trilobites.

ACIDIC OCEANS

"The whole ocean floor will record what's happening," says Professor Andy Ridgwell of Bristol University, who predicts that ocean acidification will be a tell-tale signal of worldwide atmospheric change. "It's a massive marine geological impact."

The creation of more acidic oceans will be driven by the CO_2 generated by human activity, which will create a layer of calcium carbonate, or limestone. "If geologists come along in 50 million years, the thing that will be obvious is the carbonate layer," says Professor Ken Caldeira, a climate scientist at Stanford University in California. Caldeira calculates that the carbon that humans have added to the atmosphere as CO_2 will eventually form 37,000km^3 of limestone – enough to leave a layer of limestone 30cm thick covering a third of the ocean floor.

And if future geologists drilled down through the floor, they'd see signs of acidification with a layer of dissolved carbonate worldwide. "There will be carbonate deposition, as the next hundreds of thousands of years see all of our carbon dioxide dumped," say Caldeira.

Ridgwell likens this potential signature of the Anthropocene from today's oceans to the pattern of limestone formation from a 56-million-year-old event: the 'Paleocene-Eocene thermal maximum' – the most extreme change in Earth's surface conditions since the extinction of the dinosaurs. "The increase in atmospheric carbon was comparable to our fossil fuel release, so we can expect to see a similar response," he says. "But the speed of change now is unusual."

Speed also matters for biodiversity, as extinction is not only measured by the proportion of existing species that go extinct. "In terms of magnitude, we're not living in a mass extinction – we're not even close," says Professor Charles Marshall, a palaeobiologist at the University of California, Berkeley. "But if we go by the rate of extinction, we seem to be already exceeding most of them." According to Marshall, if humans were to suddenly vanish today, many endangered species would recover quickly.

Overall then, it seems that we've changed the world, but not by much. Based on our activities so far, future stratigraphers would see the Anthropocene as a layer of limestone marking an unusual – but not extreme – climate episode. The odd long-lived trace of radioactivity from nuclear tests might provide a worldwide marker, while our rubbish and modifications to the landscape might also survive as a sign of human activity.

Geologically speaking, it seems we're not making much impact at the moment. As Zalasiewicz points out, however, climate change may lead to a different story in the future. "If we carry on with business as usual, in a few decades we'll see change on a scale not known for millions of years." ■

DR SUE BOWLER is a science writer and the editor of the journal *Astronomy & Geophysics*

Find out more

BBC ONE The three-part series ***Generation Earth*** is presented by Dallas Campbell and will be broadcast on BBC One this autumn

Last resort? Mirrors in space could reflect sunlight to cool the Earth

RELICS OF A RESCUE

Would geoengineering leave a mark on the planet?

GEOENGINEERS THINK BIG: their plans to stop global warming include forests of artificial trees sucking the carbon dioxide out of the atmosphere and fleets of ships or balloons pumping out clouds to block sunlight. Some strategies even include launching billions of tiny mirrors into space to dim sunlight before it reaches Earth. The rationale for such wild ideas is that, if successful, technical fixes such as these could bring rapid cooling – over a few decades – and buy us time to cut greenhouse gases to sustainable levels.

More down-to-earth ideas build on what researchers know about the climate cycle, mimicking the cooling effects of volcanic eruptions or boosting the weathering of silicate rocks that would naturally convert the carbon we have added to the atmosphere into limestone on the ocean floors, over a few hundred thousand years. "We have added 12,000 petagrams of carbon to the atmosphere, which equates to 100,000 billion tonnes of calcium carbonate," says climate scientist Ken Caldeira, a member of the Royal Society working group on geoengineering. "Accelerating weathering would build up the sediment layer in just a few hundred years, but it would have to be on a massive scale because you have to grind up just as much silicate rock as the limestone you make."

If we did manage to find enough energy to move and weather billions of tonnes of rock without generating more greenhouse gases in the process, the net effect would be to make the current limestone layer a bit thicker – maybe 60cm in all. Depending on the future evolution of planet Earth, that might make this Anthropocene layer even more obvious, or it might mark the start of a warmer period like the Cretaceous, when the chalk forming the 100m-high White Cliffs of Dover accumulated.

Caldeira suggests that, if we did resort to geoengineering, it might be the unusual pattern of change that stands out. "If we found a system and maintained it for thousands of years, then future geologists might find indicators of temperature that show something odd – high temperatures followed by sudden cooling," he says. "But even if humanity did something permanent to the climate, the change would be subtle."

PHOTO: GETTY, SCIENCE PHOTO LIBRARY

A VERY BRITISH DISASTE

Twenty five years ago this month, a devastating storm battered our shores. But as **Bill McGuire** reveals, our natural disasters pale in comparison with the world's worst

PHOTO: PRESS ASSOCIATION, GETTY X2, BRIDGEMAN ART LIBRARY, CORBIS, REX ICONS: INFOMEN

Far removed from a tectonic plate boundary and the tropical spawning grounds of hurricanes, the UK occupies a relatively quiet backwater as far as natural catastrophes are concerned. But we're not immune: in a normal year, floods and storms may take around a dozen lives and cause a few hundred million pounds' worth of damage.

Events such as the 1953 North Sea floods or the 1987 'hurricane' (technically a storm) occasionally bring chaos and mayhem, but even these pale in comparison to natural disasters elsewhere on the planet. Contrast, for example, the 18 deaths and £7 billion damage attributed to the 1987 storm with the 230,000 lives lost in the 2010 Haiti earthquake or the staggering $300 billion cost of the Japanese tsunami in 2011.

Looking back across the centuries, however, reveals the potential for far more devastating events to affect the UK. In our guide, we've estimated the cost of damage that would occur if the same disaster were to happen today.

Trends in our climate as the Earth continues to warm augur bigger and nastier weather hazards ahead. One of these days we may well feel the full force of Nature's wrath. Until then, perhaps we shouldn't complain too much about the odd spot of rain...

PROF BILL MCGUIRE is a geohazards expert at the Aon Benfield UCL Hazard Research Centre

1 STORREGA SLIDE TSUNAMI

Date 6200 BC
Death toll Unknown
Cost of damage £ tens of billions

Eight thousand years ago, enough sediment to fill the London Olympic Stadium more than half a million times over collapsed from the Norwegian Continental Shelf into the North Atlantic. It caused a colossal tsunami. A 25m-high wall of water surged onto the Shetland Islands, leaving behind a layer of sand in the peat as a testimony to the event.

The tsunami travelled down the east coast of Scotland, before flooding across Doggerland, a low-lying land bridge in the southern North Sea, which at the time connected the UK to the continent. The impact on the Mesolithic communities of this now-vanished land would have been cataclysmic, and it may have severed Britain's last link to mainland Europe.

WORLD'S WORST Indian Ocean tsunami (2004)
Death toll 230,000-280,000 people
Cost of damage £8 billion

The Thai island of Phi Phi following the 2004 tsunami

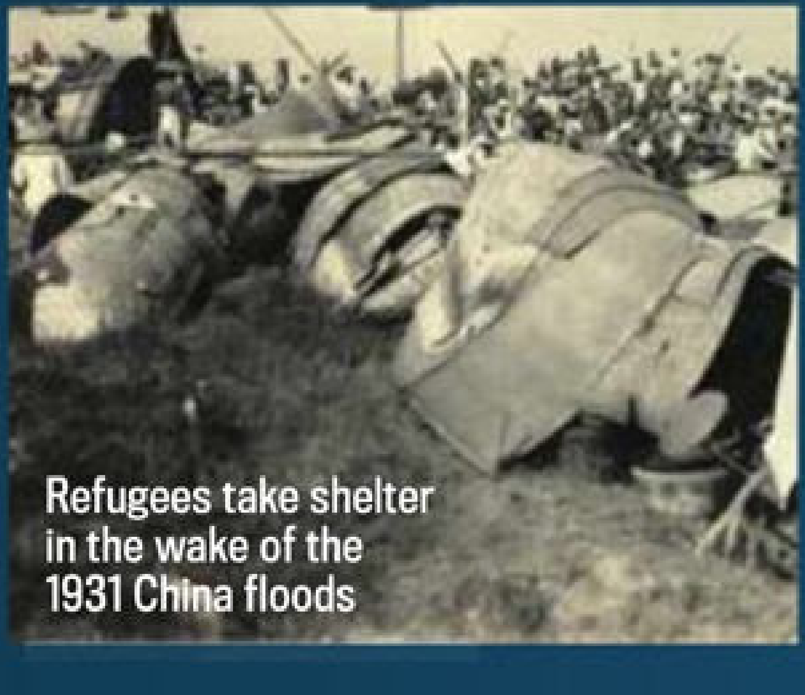
2 BRISTOL CHANNEL FLOODS

Date 1607
Death toll 500-2,000 people
Cost of damage £9 billion

On a bitter morning in January 1607, the waters of the Bristol Channel and the Severn Estuary poured across the surrounding low-lying terrain. To the south, from Barnstaple to Gloucester, and to the north, along the south coast of Wales and the northern bank of the Severn, villages were swamped by walls of water up to 7m high.

Floodwaters poured up the River Avon into central Bristol and along the River Taff into Cardiff. Although an earthquake-triggered tsunami has been suggested as the cause, it's now thought that a combination of wind-driven storm surge and an extreme spring tide provided the perfect recipe for this catastrophe.

WORLD'S WORST Central China floods (1931)
Death toll 1-2.5 million people
Cost of damage £ hundreds of billions



Refugees take shelter in the wake of the 1931 China floods

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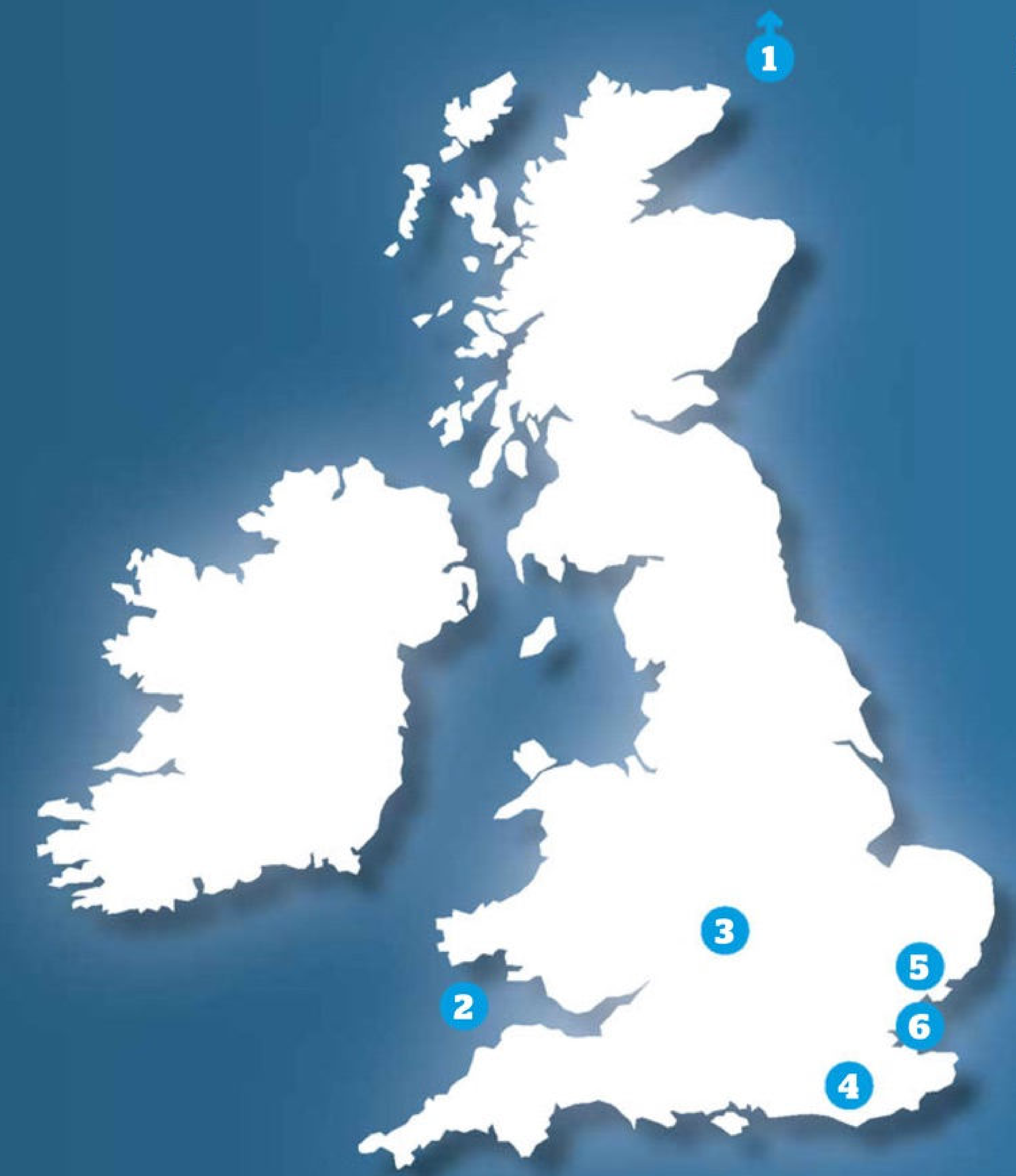


3 THE GREAT STORM

Date 1703
Death toll **123 people on land, over 8,000 at sea**
Cost of damage **£10 billion**

In December 1703, the most destructive windstorm to affect England for at least 500 years cut a swathe of devastation across Wales, the Midlands and the south.

This fast-moving cyclone drove winds that gusted up to 180km/h – comparable to a Category 2 hurricane – and caused extensive damage in London and Bristol. Daniel Defoe, a budding journalist at the time, recorded the downing of more than 2,000 massive chimneys in the capital, along with roofs torn off and the ends of gables destroyed. Over 800 homes and 400 windmills were decimated, while the sinking of over 100 ships contributed to a huge loss of life.

WORLD'S WORST **Great Caribbean hurricane (1780)**
Death toll **22,000 people**
Cost of damage **£ tens of billions**

An artist's take on the Great Caribbean hurricane

4 LEWES AVALANCHE

Date 1836
Death toll **8 people**
Cost of damage **£ millions**

Avalanches are virtually unheard of in southern England – and for such a phenomenon to take lives makes this extraordinary event unique. Located in a gap in the South Downs, the Sussex town of Lewes incorporates both steep hills and chalk cliffs. Following a blizzard on Christmas Eve, a great cornice of snow accumulated on the western edge of Cliffe Hill, immediately above a row of workers' cottages. Suggestions that residents evacuate went unheeded, so the cottages were still occupied when, two days after Christmas, the cornice collapsed, cascading more than 100m onto the buildings below. Of the 15 people incarcerated, only seven survived.

WORLD'S WORST **'Winter of Terror', Austria and Switzerland avalanches (1951)**
Death toll **251**
Cost of damage **Over £1 billion**

Destruction in the Swiss Alps – the 'Winter of Terror'

5 COLCHESTER EARTHQUAKE

Date 1884
Death toll **2 people**
Cost of damage **£ tens of millions**

With a magnitude of just 4.6 on the Richter Scale, the Colchester earthquake was small beer indeed compared to the titanic Asian quakes of recent years. Nonetheless, it was the most destructive earthquake to strike the UK since 1580 – the 20 seconds of trembling damaged 1,250 buildings in and around Colchester. Brick walls were shattered, detached chimneys crashed through roofs and churches were badly affected, with turrets and parapets damaged.

What's sometimes still called 'the Great British earthquake' appears to have occurred on a fault in ancient bedrock buried 3km down, beneath a cover of much younger sediments.

WORLD'S WORST **Shaanxi earthquake, China (1556)**
Death toll **830,000**
Cost of damage **£ hundreds of billions**

The state of Shaanxi, (shaded) was completely devastated in 1556

6 NORTH SEA STORM SURGE

Date **1953**
Death toll **307 in the UK, 2,552 at sea and in the Netherlands**
Cost of damage **£500 million**

On the last day of January 1953, residents along a 1,600km-long stretch of Britain's east coast experienced the unfolding of a 'perfect storm'. A combination of high tide and extreme storm surge resulted in water levels up to 5.6m above average, overwhelming sea defences. The scale of destruction was the worst since World War II: breaching of defences in more than 1,200 places resulted in 24,000 homes being damaged or destroyed as the sea penetrated up to 7km inland. Worst affected was Canvey Island in the Thames Estuary. The catastrophe led to the construction of the Thames Flood Barrier, designed to protect London.

WORLD'S WORST **Bhola cyclone, Bangladesh (1970)**
Death toll **500,000**
Cost of damage **£ billions**

Low-lying Bangladesh was swamped by the Bhola cyclone in 1970

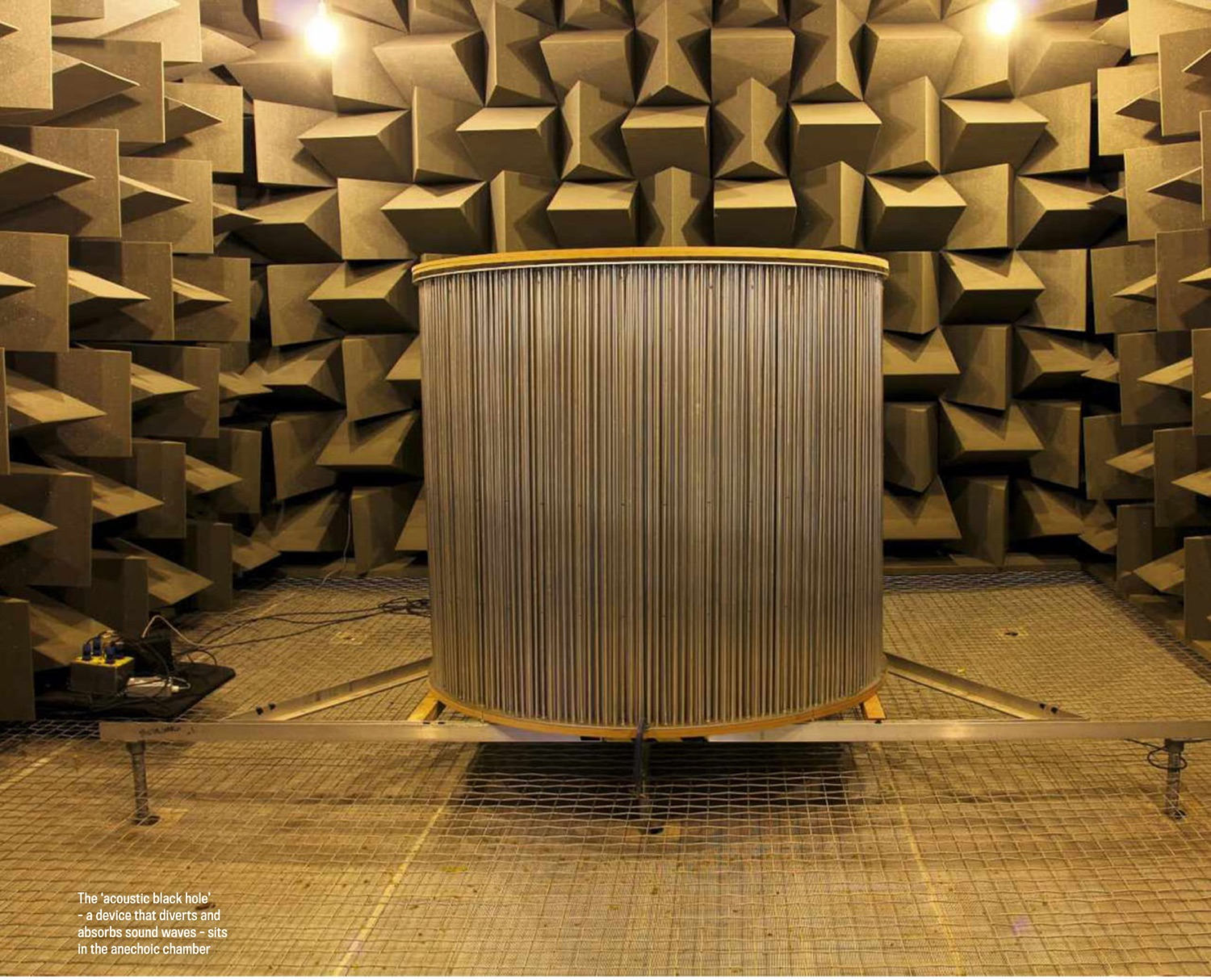
Note: 'Cost of damage' is based on if the event happened today

Dr Mark Avis places hearing defenders on the head of a test dummy to measure noise protection in an echo-free chamber

CHAMBER OF SECRETS

In a series of strange-looking rooms at the University of Salford, experts are developing technologies that manipulate sound waves. **JV Chamary** visits their labs

Photography by James Cheadle



The 'acoustic black hole' – a device that diverts and absorbs sound waves – sits in the anechoic chamber

With a background noise level of –12.4 decibels, the anechoic (echo-free) chamber at the University of Salford is possibly the quietest place on Earth. They say silence is deafening, so I can only guess that the loud noise I'm hearing is the sound of blood rushing through the vessels in my ears.

Constructed as a box within a box, the room sits on springs that minimise the effect of external vibrations. Inside the anechoic chamber, you could not only hear a pin drop, you could measure whether it makes a sound as it falls to the floor.

Except that there's no floor. Instead, a metal mesh is suspended over dozens of 1m-thick foam wedges that also cover the walls and ceiling. "The purpose of the wedge shape is to allow sound to penetrate into the wall and become absorbed," explains Professor Andy Moorhouse, head of Salford's Acoustics Research Centre, where scientists and engineers study the effects of sound in several purpose-built labs.

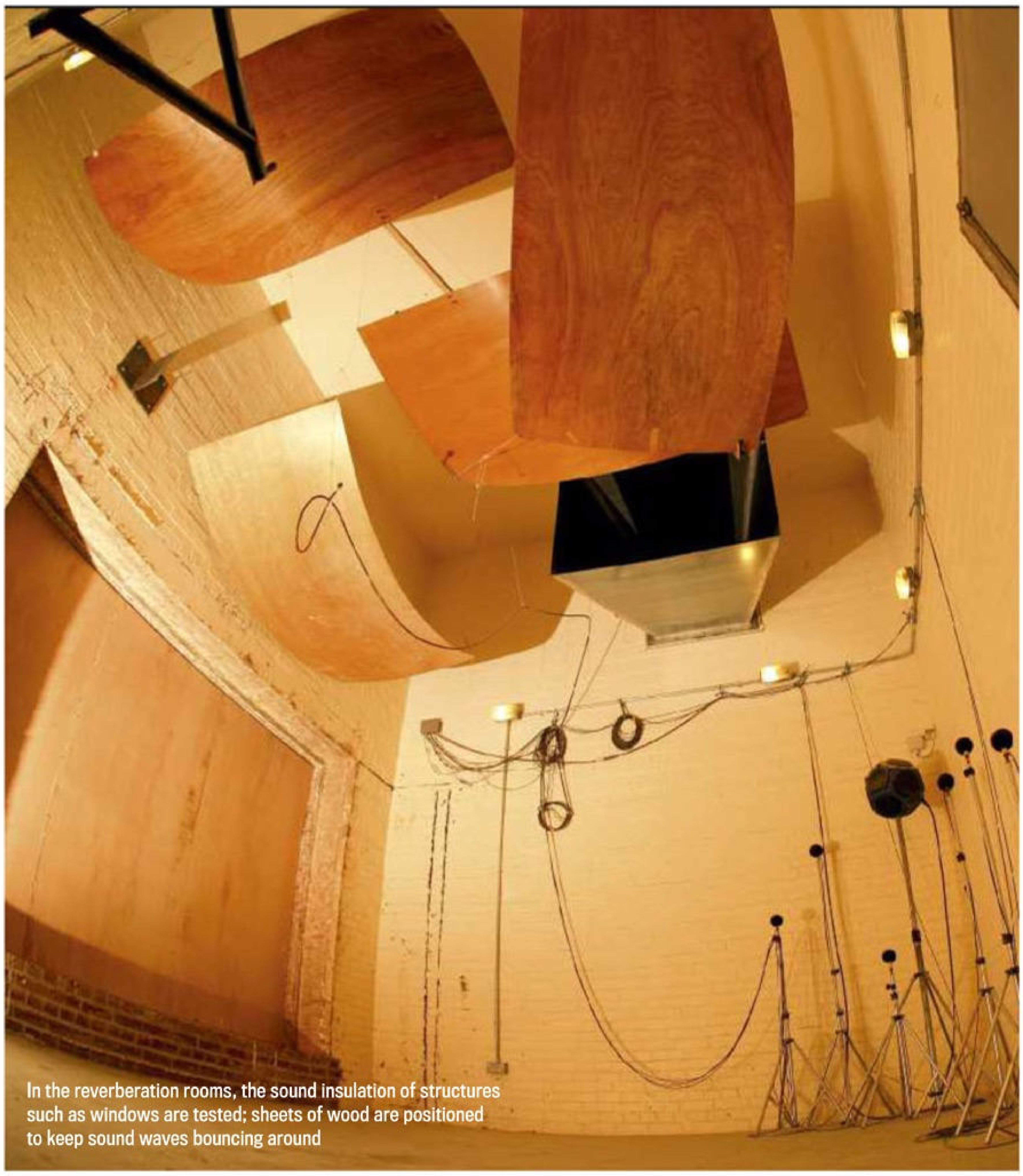
The sound-absorbing walls of the anechoic chamber mean that researchers don't have to worry about reflected sound waves messing up measurements. Inside, they test everything from hearing defenders to loudspeaker arrays, which beam sound upwards and are used in rural areas to measure wind speed – indicating where to place wind turbines. "Acoustics is an incredibly broad subject," says Moorhouse.

ANECHOIC CHAMBER

Sound-absorbing rooms enable researchers to study how sound waves are affected by people and objects. One device recently tested in Salford's anechoic chamber is the 'acoustic black hole', a 1.5m-wide cylinder of metal rods surrounding a core of porous foam. Whereas a black hole in space has such strong gravity that nothing can escape, its acoustic counterpart directs sound waves into its centre, where a foam core absorbs the waves.

The high speed of sound in air would normally cause waves to be reflected at the boundary with another medium – even an absorber like foam – but in the acoustic black hole, this reflection is blocked by 2,500 metal rods, arranged to be more tightly packed together towards the centre. This ring of rods acts as a 'metamaterial' – an artificial material with physical properties that aren't found in nature – and increases the acoustic resistance of air so the speed of sound is eventually reduced to match the speed in foam. "This matching layer gradually slows down the sound," says Dr Olga Umnova, who helped design the noise-eliminating device.

Sensitive microphones were used to test the prototype, a £30,000 project funded by the Ministry of Defence to determine whether metamaterials could absorb shockwaves from a bomb blast, although such devices could also be positioned in noisy public spaces such as train stations.



In the reverberation rooms, the sound insulation of structures such as windows are tested; sheets of wood are positioned to keep sound waves bouncing around

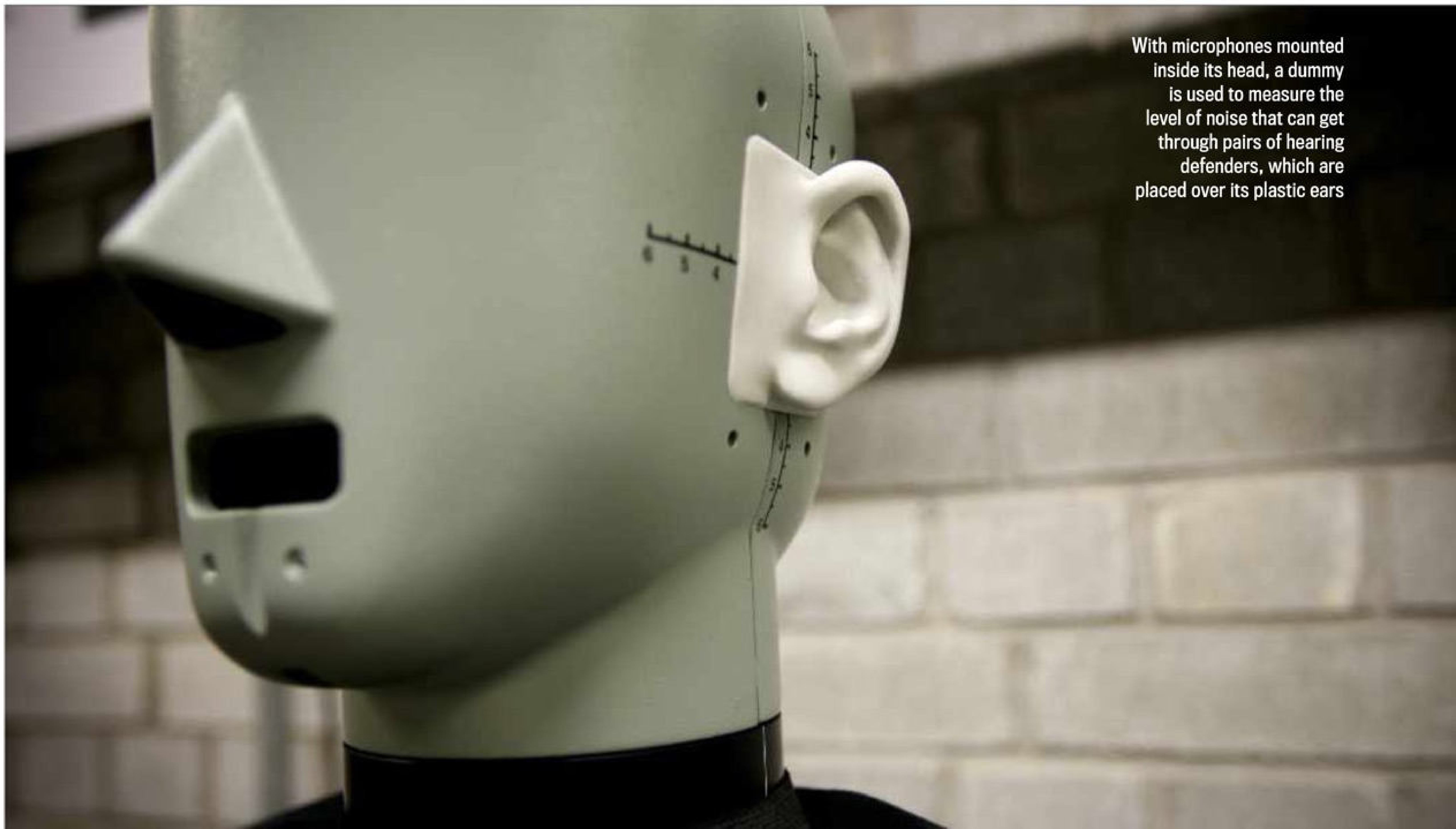
REVERBERATION ROOMS

Designed to test sound insulation, these cavernous rooms are the opposite of anechoic chambers and aim to simulate the acoustic conditions in places that don't absorb much sound, such as large railway stations and concert halls. For instance, the walls are covered with a special paint to create a hard, smooth surface that reflects sound.

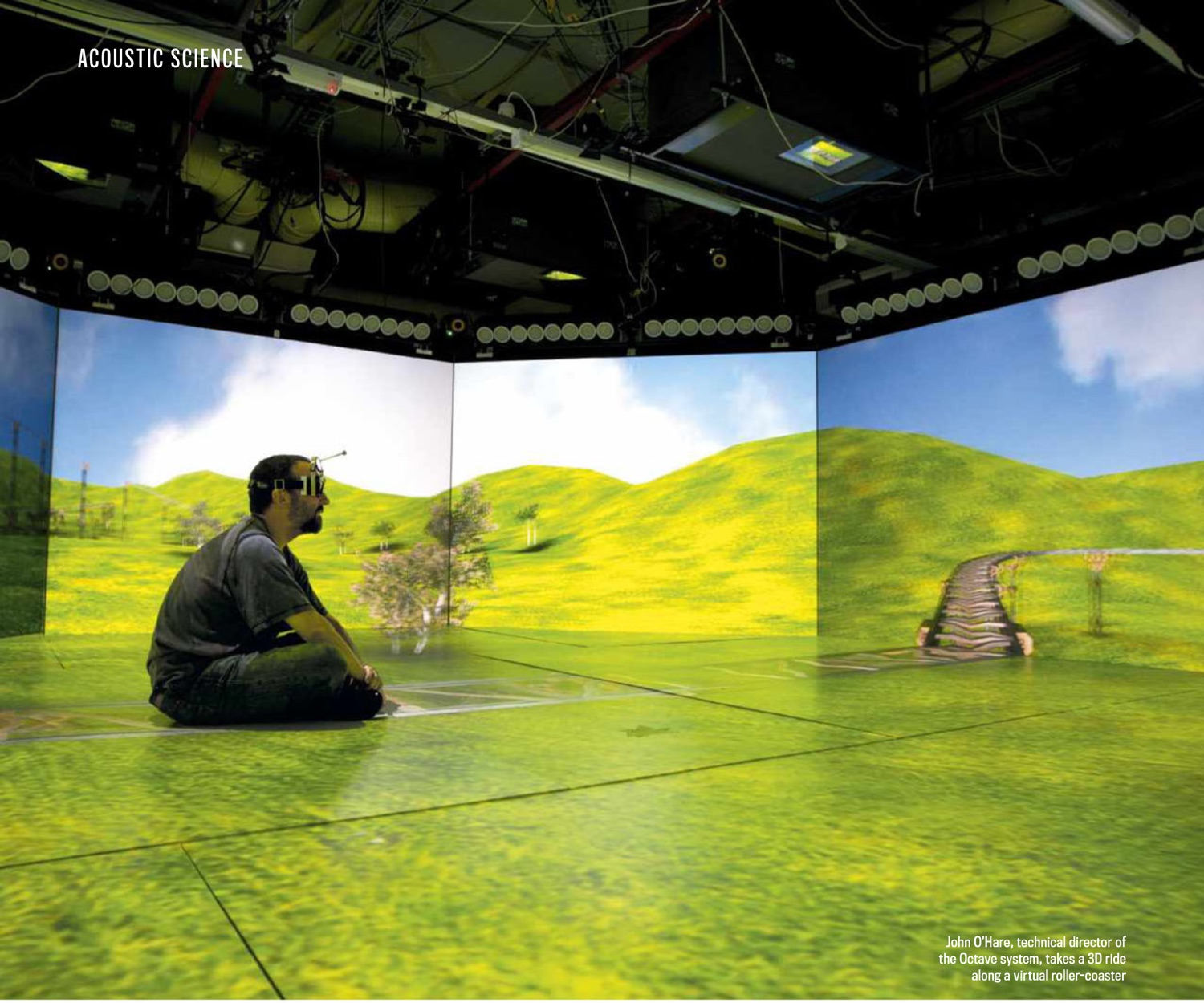
None of the walls are parallel, which prevents the accumulation of 'standing waves' that create hot and cold spots of sound, while diffusers – thin and curved sheets of wood hanging from the ceiling – help break up the sound and spread it evenly around the room.

The reverberation rooms consist of a pair of compartments: a source room and a receiver room, connected by an aperture in one of the walls. In the source room, 12-sided speakers and ventilation systems are used to generate loud noise. Microphones worth £2,000 each measure the noise levels in both rooms, values that are compared to calculate the sound-insulating properties of a structure.

The structures tested include bits of buildings and vehicles, which are assembled and positioned in the aperture. Recently, the Media City property development at Salford Quays used Salford's reverberation rooms to test studio window designs. "At the end of the tests, we would knock it all down and put something else in there," says Professor Andy Moorhouse.



With microphones mounted inside its head, a dummy is used to measure the level of noise that can get through pairs of hearing defenders, which are placed over its plastic ears



John O'Hare, technical director of the Octave system, takes a 3D ride along a virtual roller-coaster

THE OCTAVE

Images aren't the only thing you can experience in 3D – sound can be made more immersive too. In the Octave, an octagonal space, a ring of 128 speakers plays audio in a way that projects sound waves into the space by varying the volume and timing of sounds from each speaker.

This 'wave field synthesis system' takes audio sources such as pre-recorded voices and moves them around the field as dictated by a computer. The setup improves on surround sound systems like 5.1, where only listeners in the 'sweet spot' can enjoy the immersive effect. "The idea is to create a space where everybody can experience the sound and interact with it," says Dr Ian Drumm, who developed the system.

The Octave also includes cutting-edge visuals: a tracking system uses cameras to detect a user's head movements from special markers on a pair of 3D glasses, much like the motion-capture technology used in Hollywood. The images displayed on the eight projector screens are then rendered based on where the user is looking.

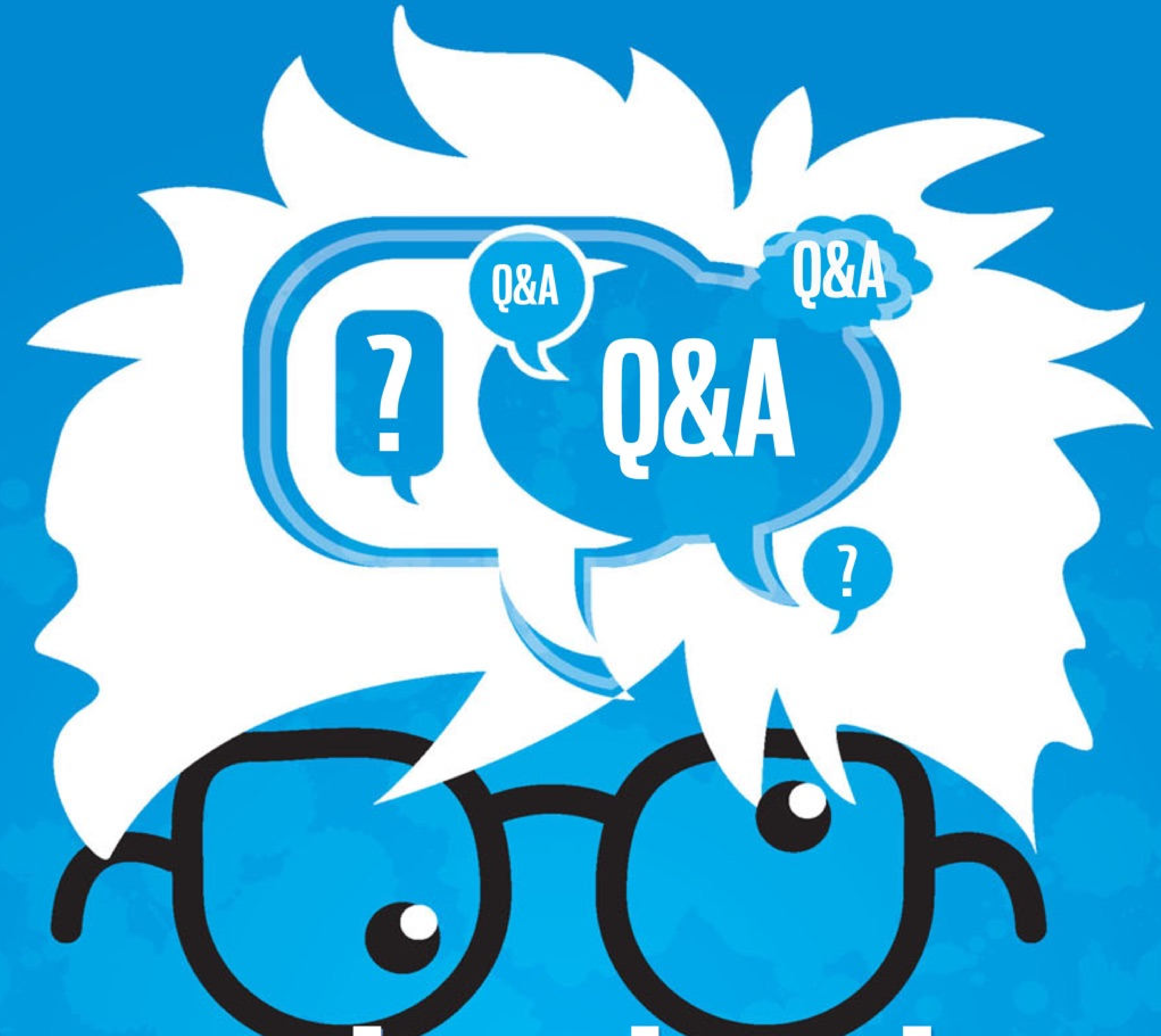
Salford's researchers are aiming to create a realistic telepresence system where people in distant parts of the world could step into an Octave-like room and interact, allowing others to see – and hear – the position of everyone in the virtual environment. For example, an international team of Formula 1 engineers could work on the virtual model of a car without resorting to air travel.

The 'wave field synthesis' system – a ring of speakers that creates surround sound – is being developed in this listening room

Find out more

http://sciencefocus.com/podcasts
Listen to an audio tour of Salford's acoustic labs on the *Focus* podcast

www.bbc.co.uk/programmes/p00q6vht
Bang Goes The Theory's Jem Stansfield visits the anechoic chamber



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David Attenborough

Wildlife presenter and TV pioneer

By Andy Ridgway

Sir David looks back at his 60-year broadcasting career and explains how science has transformed wildlife film-making

Which discovery about the natural world made over the past 60 years do you think has been the most insightful?
The acceptance that continents have drifted over geological time. Knowing that they were once in contact with one another and are now separate has made sense of so much of natural history. There are frogs in South America and Africa that are clearly related. How is it that the Atlantic Ocean lies between them? Frogs are poisoned by seawater, so they couldn't have floated across. Is it that the Almighty invented these frogs and decided to deliberately put them here and here? The answer is no – frogs evolved at a time when Africa and South America were joined and now that the continents have broken apart, they live on opposite sides of the Atlantic.

●

You've met many renowned scientists. Have there been any particularly memorable encounters?
Well, I've been lucky enough to meet some extraordinary people. But when you have the encounter, you already have a loaded mind. I have met James Watson who was, with Francis Crick, responsible for discovering the structure of DNA. I have shaken his hand and spoken with him and he seems like a nice man. But we didn't discuss important philosophical principles.

●

Is there a question about the natural world you would like answered that science has so far been unable to explain?
There are umpteen questions. I have just been looking at some sponges, the simplest kind of life you can imagine. You can completely mince a sponge – put it through a mincing machine – and put the cells back together in a solution like a soup and they will re-organise themselves and reconstitute themselves as a sponge. Well, how on Earth do they do that? And we still don't know why two oak trees growing in the same sort of space in the same sort of soil have different-shaped leaves.

●

Is there anything you covered in your earlier series that you now think was a bit scientifically naïve?
Well, I think it was very naïve of us to go around catching animals as we did in *Zoo Quest* and put them in zoos. It isn't something one would do now.

●

Has the growth in our understanding of the natural world helped us to film it?
Oh yes, certainly. The better you understand animal behaviour, the better you will be at filming it because you are more likely to understand what the animal's going to do next.

●

Have there been advances in technology that have enabled you to tell stories that you'd wanted to tell for a long time?
The ability to film in the dark has transformed wildlife television. Most mammals are at their most interesting at night and for years and years we slid over this and didn't mention it because we were unable to film them. We gave the impression that "lions are lolling around during the day – they are very idle creatures." But they are not at all, they are very active every night hunting. So infrared cameras and hypersensitive electronic cameras, 'starlight cameras', have transformed our understanding of the natural world and given us lots of opportunities for making films.

●

Do you think 3D TV will be a big part of how we tell the story of the natural world?
I think that it can be. But I think that until they solve the problem of dark glasses, which are boring to wear in the home to put it mildly, it will be difficult for 3D television to be anything other than big event television. But when it is a big event for television – I mean the final of Wimbledon or a hyper-good natural history film – it is worth doing. One of the places 3D film will become increasingly important is in the Imax cinemas that natural history museums around the world have, where they can show breathtaking things.

●

Your recent films have highlighted the impact humans have on the climate. Do you think science can solve these problems?
No, people solve problems. We have knowledge as to how to do things, but whether people do these things or not is another issue. We've got scientific ways in which people could limit the size of their families and every good reason for doing so. But do they? Not everywhere.

●

So do you think we need regulation on birth control?
I think that's very difficult to recommend – to tell people they can't do one of the most personal and important things in their lives. Who is going to be that dictator? You have to convince people that it is better. ■

Find out more

BBC TWO The three-part series **60 Years In The Wild** will be screened on BBC Two in November. See RadioTimes.com for details.

PHOTO: GETTY, BBC X3

The Age of Attenborough

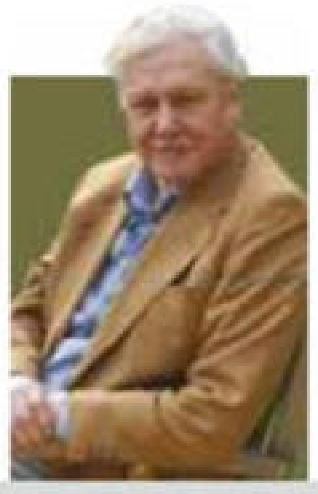
1952
Joins the BBC as a producer. He's discouraged from being a presenter due to his big teeth.

1954
Presents *Zoo Quest*, in which he travels to a tropical country to help capture animals for London Zoo.

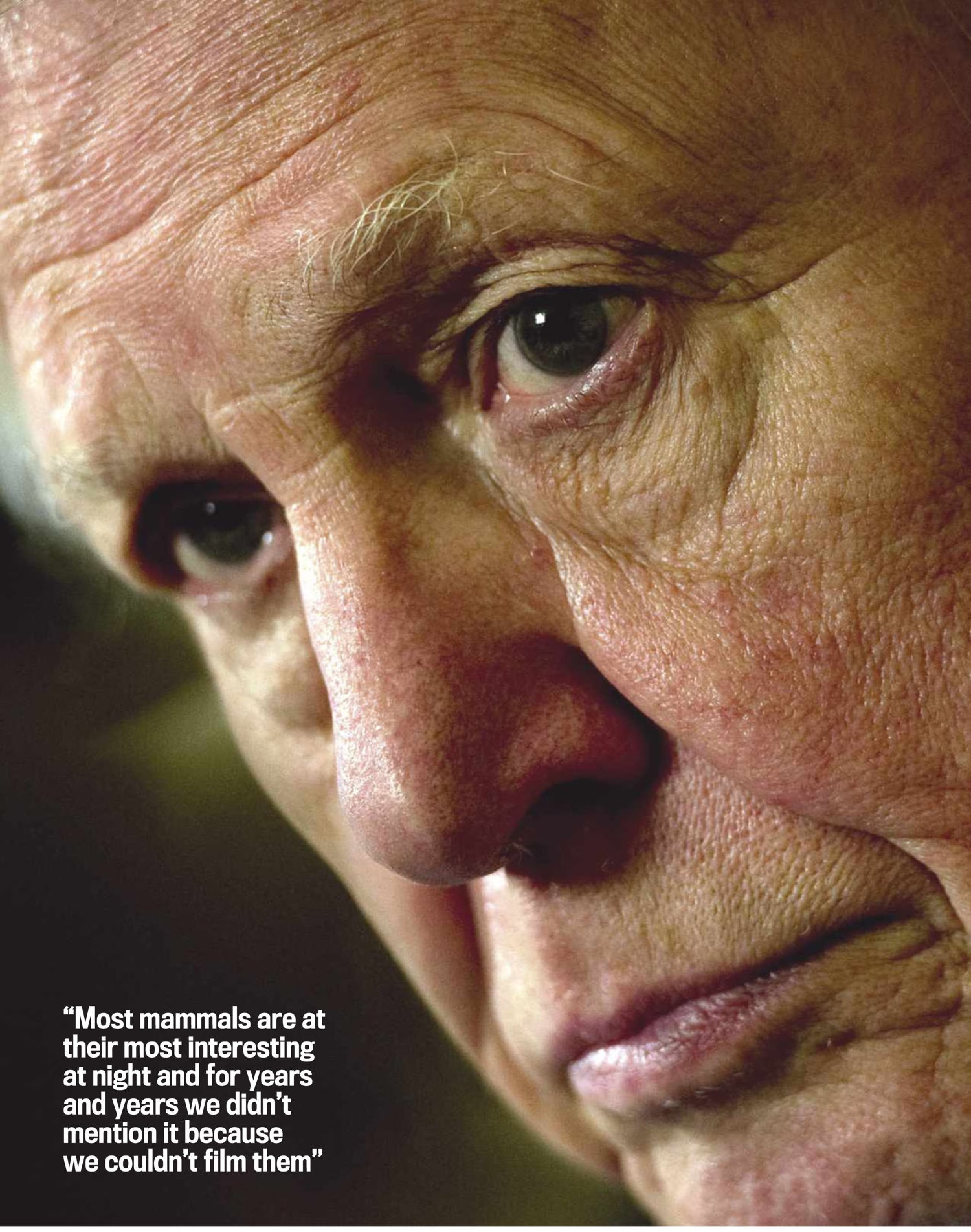
1965
Appointed controller of BBC Two, commissioning *Monty Python's Flying Circus*.

1977
Narrates the first episode of *Wildlife On One*, a series which goes on to run for a further 252 episodes.

1979
Life On Earth, the first of Attenborough's acclaimed *Life* series, is aired.



2006
Narrates *Planet Earth*. All the footage, filmed in 62 countries, is recorded in hi-def.



“Most mammals are at their most interesting at night and for years and years we didn’t mention it because we couldn’t film them”

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MARS
THE DRESS REHEARSAL

Curiosity is the most capable rover yet, but astronauts will still be needed to truly explore Mars. **Sean Blair** looks at the next-generation space suits that they'll wear on the surface

PHOTO: KATJA ZANELLA-KUX/OEWF

NASA'S CURIOSITY ROVER, which reached the surface of Mars this summer, can't help but make the Red Planet look inviting. Its MastCam offers an astronaut's eye view of a strikingly Earth-like terrain. The trouble is, any unprotected human explorer would drop dead in Mars's frigid CO_2-filled atmosphere.

NASA may not be planning to send humans to Mars until the mid-2030s, but research teams are already developing and testing space suits for such a mission. The Human Spaceflight Laboratory at the University of North Dakota has tailored a Mars-specific suit, the NDX-1. "NASA's current space suit weighs around 200kg," explains designer Pablo de León. "That's fine in zero gravity but in Mars's one-third gravity it would weigh 70kg. It would be like carrying another person around."

Any Mars suit also needs to take account of fine Martian dust. The soil is red because it's largely composed of oxides of iron and other minerals. Some scientists suspect it could be sufficiently oxidising to give a chemical burn on unprotected skin, like strong bleach, and it may also contain toxic metals such as arsenic.

Like all space suits, the NDX-1 resembles a wearable balloon, with accordion-like joints to facilitate movement. The wearer's whole body must remain under pressure to prevent bodily fluids such as saliva boiling.

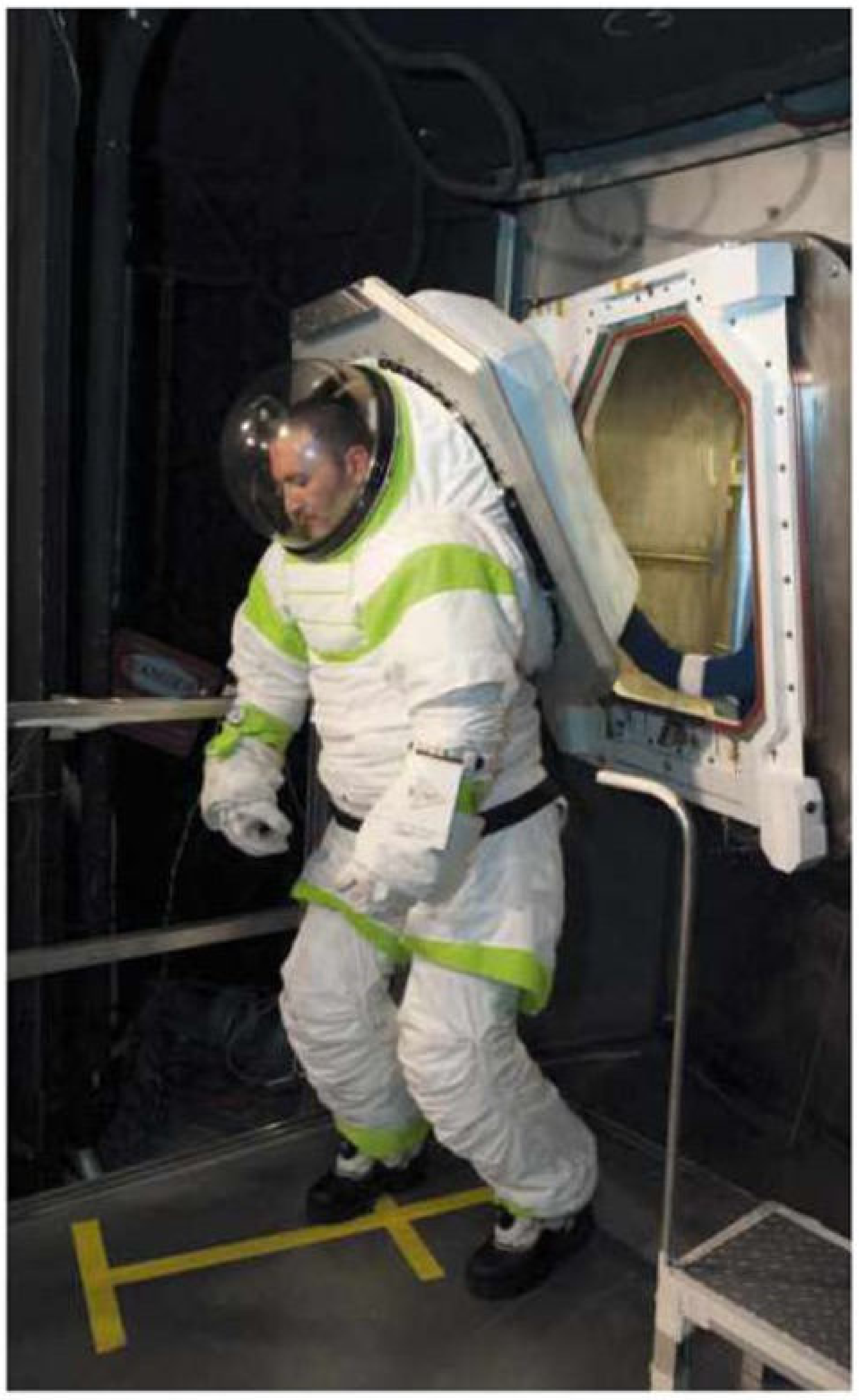
Where the NDX-1 is designed just for Mars, NASA's Z-1 is a more general-purpose suit for the Moon, space, Mars and asteroids. With it, the agency is also investigating a 'suitporting' system to stop spacecraft being contaminated (see 'Suiting up outside', opposite).

With the Aouda.X suit, non-profit group the Austrian Space Forum is looking at a specific issue – how an astronaut would interact with a 'smart suit'. "What the 45kg suit does is help evaluate advanced human-machine interfaces such as biomonitoring sensors, voice recognition, video links and a heads-up display," says developer Alexander Soucek.

"It will take a lot of work to put people on Mars," he continues. "Our research forms just one small piece of that mosaic."

CAVE TESTING
Earlier this year Aouda.X was put through its paces in a frigid ice cave in the Austrian Alps. Researchers have a keen interest in Martian caves: many cave entrances have been spotted, and such subterranean shelters may offer refuge to any surviving Mars life. Essentially a wearable computer, Aouda.X is designed to make a Martian explorer self-reliant. Current suits have telemetry monitored by Mission Control on Earth, but Mars's distance from us means future Mars walkers will need to monitor their own air pressure, temperature and CO_2 levels. Next year the suit, linked by satellite to a control room at Innsbruck University, Austria, will be part of a large test in Morocco.

PHOTO: KATJA ZANELLA-KUX/OEWF, NASA X2, REUTERS



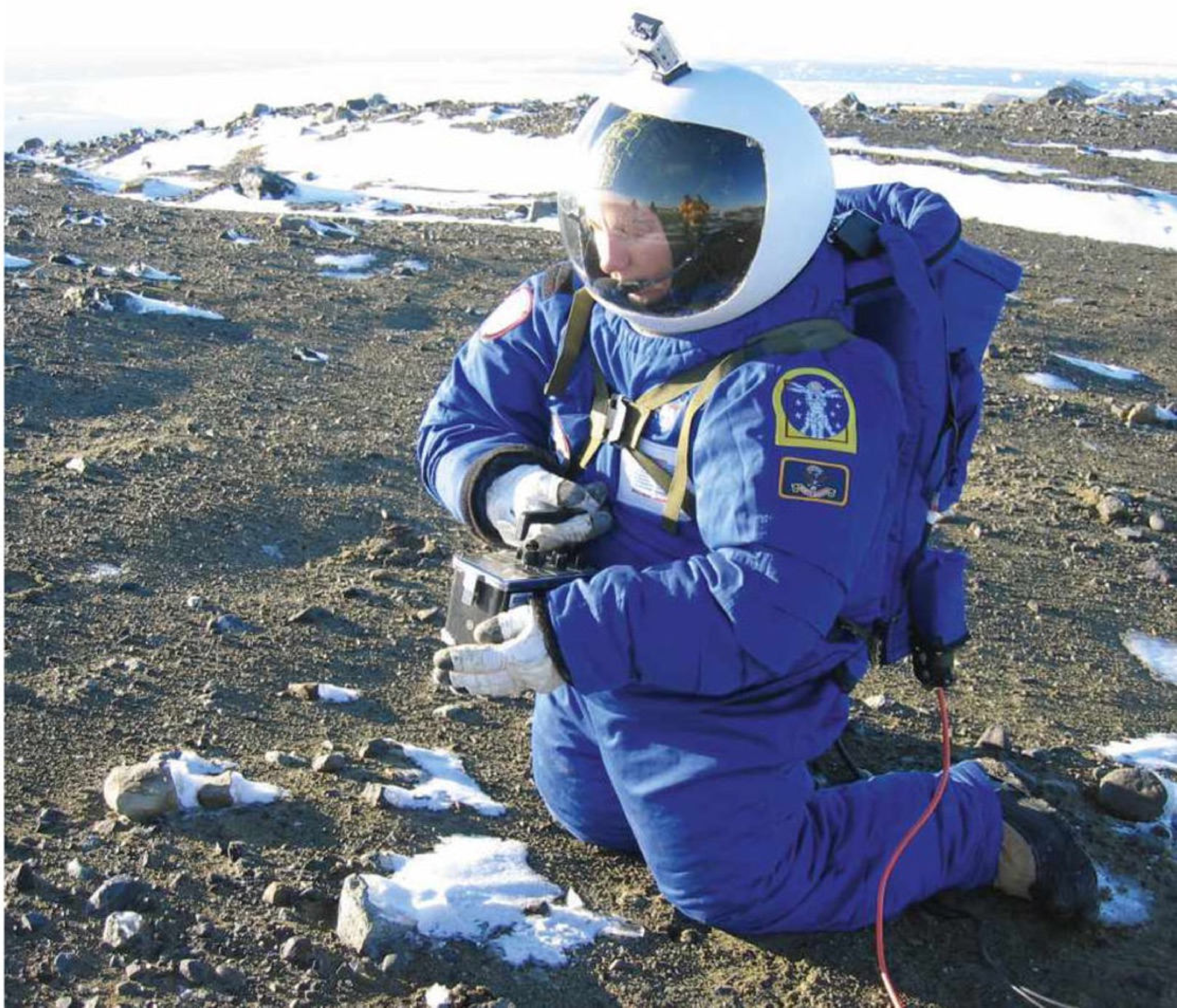
SUITING UP OUTSIDE
Keeping space suits outside the landing vehicle – something that's never been done before – would be a way of controlling dust exposure. The 'suitporting' concept, tested here by the Z-1 space suit team at NASA's Johnson Space Centre in Texas, involves astronauts stepping straight into suits docked outside. But for this to work, cabin and suit pressures need to be equal.

"The International Space Station's internal pressure is close to terrestrial sea level, but inflating a suit like that would billow it up like the Michelin Man," explains spacesuit designer Pablo de León. Instead, suits operate on pure oxygen at one-third cabin pressure. Like scuba divers, spacewalkers must pre-breathe pure oxygen for several hours beforehand in order to adjust.

SEAN BLAIR is a journalist who works for the European Space Agency

ANTARCTIC ACCLIMATISATION
The surface temperature on Mars can vary immensely, from lows of about -140°C over winter at the polar ice caps to highs of 35°C in equatorial summer. So the NDX-1 has been tested at a large number of terrestrial Mars analogues, from Utah and Australia to Antarctica.

In the Mars To Marambio mission (seen here), named after the Argentine Antarctic base, scientists went on simulated spacewalks, operated drills and collected samples while wearing the suit. The suit's heating system warms the boots, gloves and chest. Permafrost – permanently frozen ground – surrounds both Martian poles, and Marambio was selected for the development work because it offers easy access to permafrost here on Earth.



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Now available on the high street, exclusively at RICHER SOUNDS

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BEST BUY
HI-FI CHOICE
magazine

Small enough to pick up with one hand yet big enough for a lifetime of music, the Brennan JB7 is one man's brilliant idea for everyone's forgotten music.

Key features

- Browse albums by spinning the volume knob - push to play
- Display track names as they play
- Delete tracks you don't like
- Seven rainbow colour coded playlists
- Segue function blends one track into the next
- One touch record from vinyl, cassette or radio
- One button plays the entire music collection at random
- Plays MP3 downloads - future proof
- Clock with alarm
- 60 Watt, 4.8 x 16 x 22 cm steel and aluminium construction
- Backup music to external USB hard disk for safe keeping
- You can use it with your existing hi-fi or on its own

Introducing the new and truly amazing Brennan JB7

What's the point in owning hundreds of CDs worth thousands of pounds if you never listen to them? The problem with CDs is that it's quicker to make a cup of coffee than dip into a CD. Try timing how long it takes to pick a CD, load it in the CD player, play a snippet from a track or two, eject it and put it back where it came from. Then there is the problem of finding music. The print on a CD spine is tiny. What if the track is on a compilation CD? What if the CD is in the car? Then there is the clutter. You need to keep your CDs near the player or you won't play them. So you are forced to share your living space with literally hundreds of cheap plastic boxes.

CDs are a great way to listen to music but they are also inconvenient, inaccessible and a bit of a chore.

The Brennan JB7 is a CD player with a hard disk that stores up to 5,000 CDs* - and that's not all

It saves space and clutter and delivers near immediate access to an entire music collection. JB7 owners rediscover then fall in love with their music again simply because the Brennan makes it so accessible.

The Brennan also records from vinyl and cassette so you can enjoy your entire music collection but keep the originals in another room or retire them to the attic.

Over 30,000 sold. Lots of happy customers.

"Until you actually own a Brennan or at least see one operating, you can't really put into words how wonderful and amazing it is. You wonder how something so small, compact and stylish can do so much! Now, with the touch of a button on the Brennan, it randomly plays music and I no longer have to make such decisions by myself. It makes them for me." Mr G. Patterson, N. Ireland

The Brennan JB7 is available in Cobalt Blue or Titanium Metallic

MONEY BACK GUARANTEE

If you're not suitably impressed with your Brennan JB7 we'll collect it free of charge and refund you in full.

*See copyright message on the Brennan website

The face behind Brennan

Martin Brennan, who designed the JB7, has worked with Sir Clive Sinclair and Sir Alan Sugar and has designed over 20 silicon chips in his career. He was a real pioneer in the computer games industry - he played a central role in the design of the worlds first 64 bit games computer.

Ever since CDs were invented Martin wanted a CD player that would hold his entire CD collection. He wanted something as simple to use as a light switch but at the same time something that would let him find a particular track without leaving the armchair.

A word about copyright

"In 2006 the record companies said unequivocally that they are happy for you to load your own CDs onto a hard disk but the Advertising Standards Authority have asked us to tell you that it is unlawful to copy material without the permission of the copyright holder."

Martin Brennan

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THE FUTURE OF GADGETS

TECHHUB

EDITED BY **DANIEL BENNETT**

THIS MONTH

BILL THOMPSON
On logging your life
p77

JUST LANDED
LG's 4mm-thick TV
p78

ULTIMATE TEST
The Cube 3D printer
p81

Game changer: the Ouya is the size of a Rubik's Cube and packs a quad-core processor

ON THE HORIZON

THE OUYA GAMES CONSOLE

Ouya could soon be the word on every gamer's lips, even if it does have a name that sounds like someone stubbing their toe. This diminutive home console promises to usher in a new era of gaming, using Google's Android framework to fuel a cheap and flexible alternative to the wallet-bothering demands of the Xbox 360 and PlayStation 3.

The concept here is to marry cost-efficient technology with a fresh approach to gaming: a compact design, affordable price tag, and an emphasis on supposedly 'free' experiences. And thanks to Android's open nature, Ouya hopes to attract a new generation of developers who are hungry to innovate

Ouya will come with a dual-stick wireless controller similar to the PS3's

and take risks. Think smaller games with bigger ambitions, rather than yet another *Call Of Duty* sequel.

Coming with its own twin-stick controller, the Ouya itself is the size of a Rubik's Cube, so while it's yet another box to fit under your HDTV, this one won't take up much space. Inside you'll find 1GB of RAM and a quad-core Tegra 3 processor, the same chip you'll find in today's upper-end Android tablets. The new console may not be giving the PS3 a run for its money, but it'll be no slouch either: the Tegra 3 can already handle the likes of *Sonic The Hedgehog 4*, and we'll supposedly see an Ouya version of *Minecraft* too. It also supports cloud gaming, where the graphical gruntwork is handled by remote machines and streamed to the console.

Android gaming is typically defined by disposable commuter fare, but Ouya clearly wants to cast off this image in favour of something more respectable. In theory, the end result should be a machine that combines a serious gamer's philosophy with a broad selection of interesting, risky titles.

And regardless of whether or not it achieves this lofty goal, it should be cheap enough simply to give it a go: Ouya is slated to cost just $99, while each and every game will be free – to some extent, at least. In this case 'free' could simply mean a limited demo, or a complete 'freemium' experience, that allows players to buy in-game items.

If you're thinking this all sounds rather swell, you're not alone: Ouya raised a whopping $8.59m (£5.47m) during its month-long funding drive on Kickstarter, and it's also won the support of several key industry allies – including Final Fantasy publisher Square Enix, and streaming games service OnLive. Thanks to a partnership with the latter, Ouya users will be able to play massive commercial hits like *LA Noire* and *Batman: Arkham City*.

But not everyone is convinced. Andrew Smith, designer of the BAFTA-winning *Flock!* believes that the console may struggle to establish the gaming utopia it promises. "It is always nice for indies to have access to a new open platform, but I expect money to start talking sooner rather than later, pushing the indies into the corner just as we see on most platforms currently," he says.

Ouya won't launch until some point in 2013. By then it's likely that Apple and Google will be pushing their presence in the growing Smart TV market, and next summer should also find Microsoft and Sony revealing new gaming hardware. The console's success is therefore far from certain, but it has managed to gather an impressive level of buzz in a very short space of time. Come next year, Ouya may well be something to shout about.

NEON KELLY is deputy editor at *Videogamer.com* and writes *Play* on p109

TECHOMETER

WHAT'S HOT

DRIVERLESS CARS

Google's fleet of robot motors has now completed 300,000 accident-free miles on California's roads. To put that in context, the average UK family is thought to cover around 10,000 miles per year. But don't throw your driver's licence out the window just yet. Google says it's still fine-tuning the autonomous system to master roads that are covered in snow or disrupted by roadworks. The next phase of testing will see a group of Google employees using the cars to commute to work.

WHAT'S NOT

BUTTON-BASED REMOTE CONTROLS

These days TV remotes tend to have more nobs and buttons than a nuclear power station. Now Samsung and LG have ditched the clunky, traditional remote in favour of motion- and voice-control systems on their flagship TVs, while other manufacturers offer smartphone apps for controlling your set. We've tested them all, and each option is infinitely better for navigating around menus, which now boast catch-up TV, web browsing and access to social networks.

READER POLL

Would you buy an Ouya? Here's what readers have said so far. Add your opinion at http://j.mp/OuyaPoll

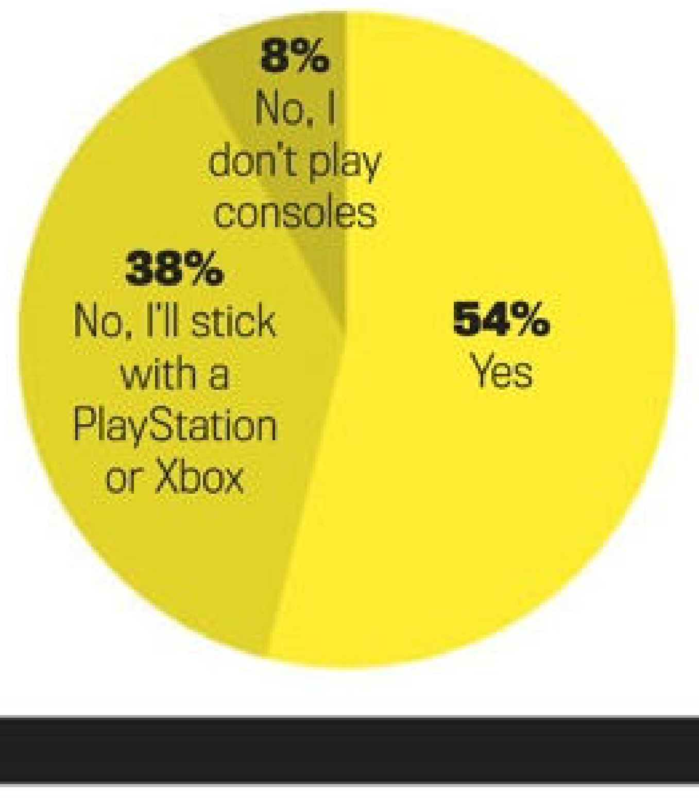

PHOTO: GOOGLE X2, ILLUSTRATION BY LAUREN GENTRY

EARLY ADOPTER

BILL THOMPSON

Live longer: become a lifelogger

Burning just over 2,000 calories the other day, I walked 10,000 steps and climbed 11 staircases. I know this because for the past few months I've been walking around with a Fitbit pedometer attached to my belt, and it told me so.

Like the Nike FuelBand and many other alternatives, the Fitbit helps me keep track of my activity, and it's changed the way I live. I now walk up stairs and have even been known to get up and pace around during long meetings just to 'get my steps up'.

In short, I've become a lifelogger: someone who turns their daily life into a data feed. Of course, I'm really an amateur at this. I don't carry a GPS receiver, but rely on the geotags on my photos to tell me where I've been, and I haven't started using an app like Daytum to track my mood, how much coffee I drink, or any of the other aspects of daily existence that could be turned into data.

I'm nothing like Microsoft's Gordon Bell, who has been recording every aspect of his life for a decade, including papers, photos, pictures, presentations, home movies and voice recordings. Nor am I like the mathematician Stephen Wolfram, who has recorded masses of data, including every keystroke he has typed on his computer for over 20 years. Wolfram has published a detailed analysis of this data, and apart from the steady increase in the number of emails he deals with each day there's a degree of regularity to his life that you might find surprising.

The data isn't just interesting to the person who creates it, of course. Facebook acquired Daytum last year and it will surely turn the now familiar Timeline into a place for structured data on things like exercise and moods, instead of just a collection of photos and updates. Of course, their ultimate goal will be to target advertising more precisely by replacing junk food ads with health supplements for someone who is running regularly, for example.

Mood monitors

But it's not just hungry advertisers who'll be salivating over this vast source of data. Psychologists are already using data from mood tracking apps like MoodPanda and T2 Mood Tracker to observe trends on a national scale. This has the added advantage that they can pair traditional questionnaires with a user's location, time of day and any other data a smartphone can harvest.

A smartphone is all you need to record data that previously required special equipment, and it can all be seamlessly uploaded to websites for tracking, analysis and comparison. But doing this raises many questions, especially at a time when governments around the world are seeking the ability to monitor our online communications.

Lifelogging could become the equivalent of genetic testing, requiring special laws to stop employers, insurance companies or advertisers from using the data in ways that go against someone's best interests.

Or we might decide that the price is worth paying. After all, living my life in public on Twitter and Facebook makes me feel connected to people who share my interests. Personally, lifelogging has made me feel fitter and I have fun comparing walking steps with friends. And for now, the loss of privacy is a price I'm happy to pay to live longer.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

TELL US WHAT YOU THINK!
Visit our forum at sciencefocus.com/forum

COMING SOON

3 MONTHS

NINTENDO WII U

Start saving your money for Christmas, because the Wii's successor is here in December. The motion-controlled gaming is still present, with a new controller that features a built-in screen. Nintendo says that this will cater to hardcore and casual gamers alike. Either way, it looks like nothing we've ever played before. *Nintendo.com*

+ **iPhone 5** Rumoured changes include a bigger screen, a new design and NFC payment technology. *apple.com*

+ **Basic Band** An accelerometer, heart rate tracker, thermometer and sweat sensors are all packed into this wristwatch that tracks and visualises your personal health. *mybasis.com*

6 MONTHS

MICROSOFT SURFACE

We're excited to see Microsoft's take on the tablet. Details are scarce, but we're intrigued by the tablet version of Windows 8, which it's said will continually be in touch with your PC to give it access to everything on your home computer. Plus, a case that incorporates a keyboard and touchpad is certainly tempting. *Microsoft.com/surface*

+ **Lytro** This camera lets you select your focus *after* the picture's taken. *Lytro.com*

+ **Nest** A thermostat that could slash your bills. It adapts to your habits to heat your economically. *Nest.com*

9 MONTHS

PROJECT GLASS

We'd definitely like to be first in line to try a pair. Messages, maps and information are overlaid on top of your vision. Sat-nav with arrows superimposed over the real world sounds great, but we're not so keen on the idea of pop-ups obscuring your view while you drive. *j.mp/projectglasses*

+ **Xbox 720** Leaked documents, Microsoft job vacancies and one controversial eBay auction, point to a release next year for the console codenamed 'Durango'. *xbox.com*

+ **Facebook phone** Facebook's hiring of former Apple and Palm employees suggests its own phone is in the works. *facebook.com*

JUST LANDED

SLIVER SCREEN

Just 4mm thick and with the most life-like pictures yet, **Jamie Carter** tests the world's thinnest TV

LG 55EM960V, £6,500, WWW.LG.COM/UK

By using OLED technology and incorporating all the circuitry in the base, LG's new set is just 4mm thick

THE DEPTH OF a couple of credit cards, this 55-inch set from LG goes on sale this autumn for a cool £6,500. It's the first big-screen TV to use super-sharp Organic Light Emitting Diode (OLED) technology.

How is it so thin?

A conventional flat screen relies on a chunky backlight to make the picture viewable. OLED TVs instead use a naturally phosphorescent film that emits it own light when an electric current is passed through it. This removes the need for a separate light source, so the screen need only be as thick as a sheet of this material.

LG has also put as much of the circuitry as possible in the desktop stand, making this set even slimmer. Just as impressively, a carbon fibre shell cuts the weight down from 30kg to 10kg.

Does OLED improve picture quality?

Hugely. Immediately noticeable is the inkiness of total black, which made a huge difference to the impact of murky sequences in films. The added contrast also delivers more intense colour.

With no backlight, which tends to bleach a picture, the contrast is 100 times more than LCD TVs. The result is a far more dynamic picture, though just as impressive was the response time of the screen. Camera pans or motion sequences, such as a speeding car across the screen, didn't cause a distracting blur. It really is a huge leap forward over the current technology.

Is this new technology?

Not exactly. Sony sold an 11-inch OLED TV four years ago and LG a 15-inch version back in 2010 (over 1,000 were sold). This is the first to show 3D and to include a white pixel. By adding a white sub-pixel to the usual red-green-blur colour mix used in TV, LG's OLED boosts the colour range and accuracy, with blue in particular more accurately represented.

What else can it do?

Despite its crash diet, this set has all the latest TV tech you'd expect, including seven pairs of 3D glasses and LG's Cinema 3D system. Powered by a dual-core processor and built-in Wi-Fi, LG's Smart TV platform includes the BBC iPlayer, YouTube, Lovefilm and Netflix. It's all controlled by a 'magic' remote, which feels very similar to using a Nintendo Wii.

Will OLED TVs catch on?

Certainly. Samsung, Motorola and Nokia have smaller OLED screens in their smartphones, while Samsung, Panasonic and Sony are committed to making OLED TVs later this year or next. LG expects OLED to go mainstream within about three years, and it should do; it's more impressive than your first glimpse of hi-def TV. This really marks the next era in home cinema.

Jamie Carter is editor of *Home Cinema Digest*

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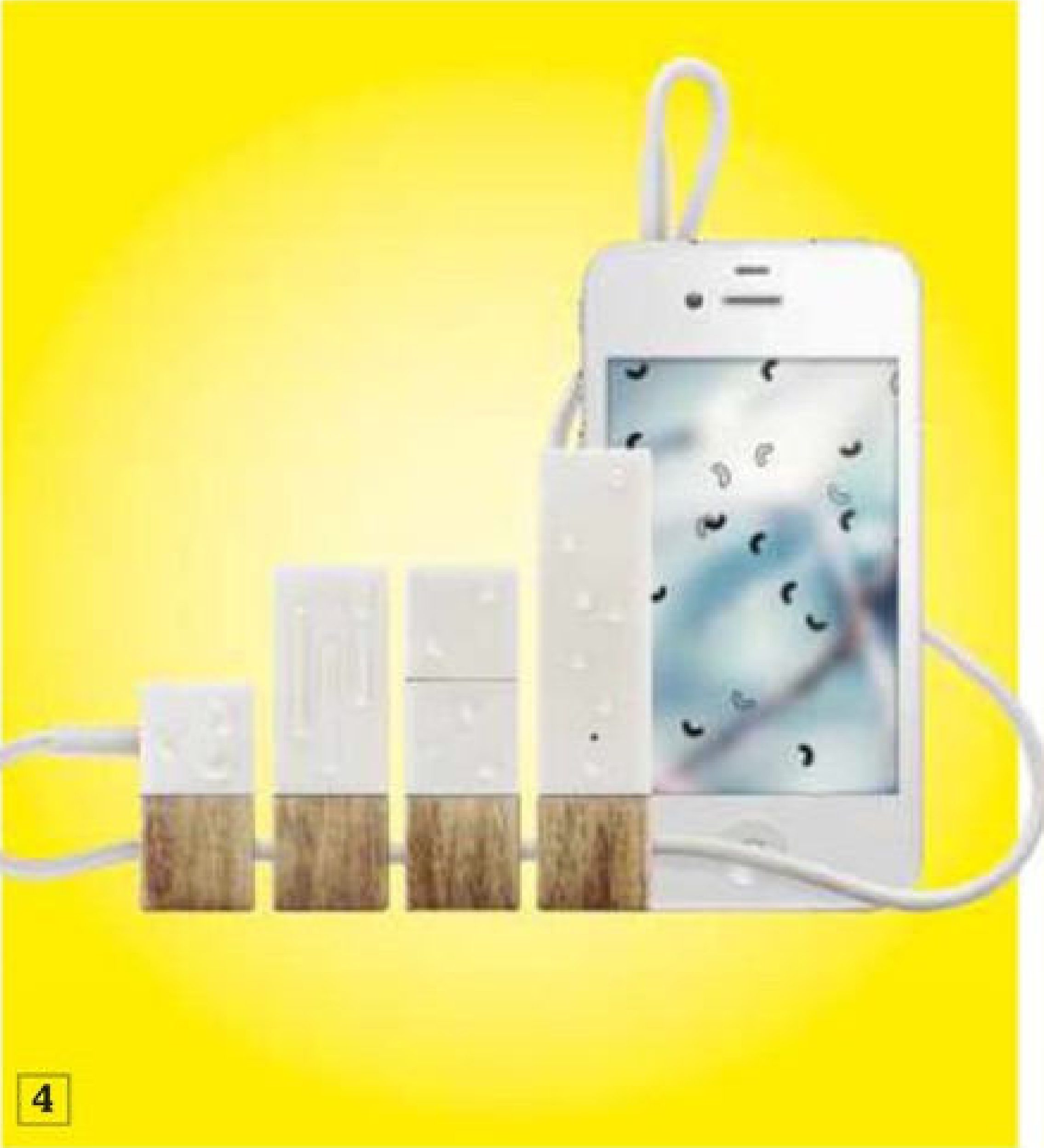
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5

6

APPLIANCES OF SCIENCE

1 OPEN SESAME

If you've got sensitive files you want to lock away on a USB memory drive, then there's probably no more secure key than your own voice. Plug this USB into a laptop, tell it your password and only you and Jon Culshaw will be able to access it. And don't worry, there's an alternative entry method if you get laryngitis.

Hammacher Schlemmer Voice Activated USB drive
www.hammacher.com; $49.95 (£31.81) plus P&P

2 ROUGH AND TUMBLE

Turn an iPhone 4S into your very own action cam with this rugged water-, shock- and dust-proof case. Like the more expensive GoPro Camera, it includes an array of mounts for your death-defying sport of choice – from a skydiving helmet fitting to waterproof surfboard attachments. And it's got a wide-angle lens to improve the viewing range of the phone's camera to take in all the action.

Mophie Outride
Mophie.com; price TBC

3 WHEELIE GOOD

On flat surfaces a tyre filled to a high pressure rolls faster, while on a rocky surface a low-pressure tyre provides better grip. The Adaptrac system lets you adjust your tyre pressure on the move thanks to a compressed gas tank fitted to the bike's downtube. Buttons and pressure gauges on the handlebars let you adjust each tyre's pressure to precisely match the terrain beneath you.

Adaptrac Tyre
adaptrac.com; price TBC

4 IPOD TRICORDER

This unassuming set of devices is actually a collection of sensors that feed data into your iPhone. It'll tell you how much radioactivity there is in your surrounding area, how organic your food is (via the presence of nitrates), the humidity of the air and the strength of any electromagnetic fields around you. Now we've never found ourselves wondering about any of the above, but now there's a gadget that will tell us, we're curious.

Lapka
mylapka.com; price TBC

5 POWER STATION

This white block is a battery pack that carries enough juice to fully recharge an iPad. The idea is that you buy as many of them as you need and stack them on top of each other underneath the base charging unit. To charge them you just stack as many as you like under the base unit, which also connects them to your gadgets. A dozen should give you juice for a couple of weeks.

Exogear Evovolt Plus
exogear.com; base unit: $89.95, sub units: $49.95

6 PAD AND PEN

Touchscreen tablets are great for improving your productivity, but they still don't beat a pen and paper when it comes to taking notes. Casio Japan has created a happy medium: an Android-based tablet that can capture your scribbles on the adjacent notepad and turn them into an editable digital file. It does this via the tablet's front-facing camera, which will also scan business cards into your contact book.

Casio Paper Writer
Casio.co.jp; price TBC

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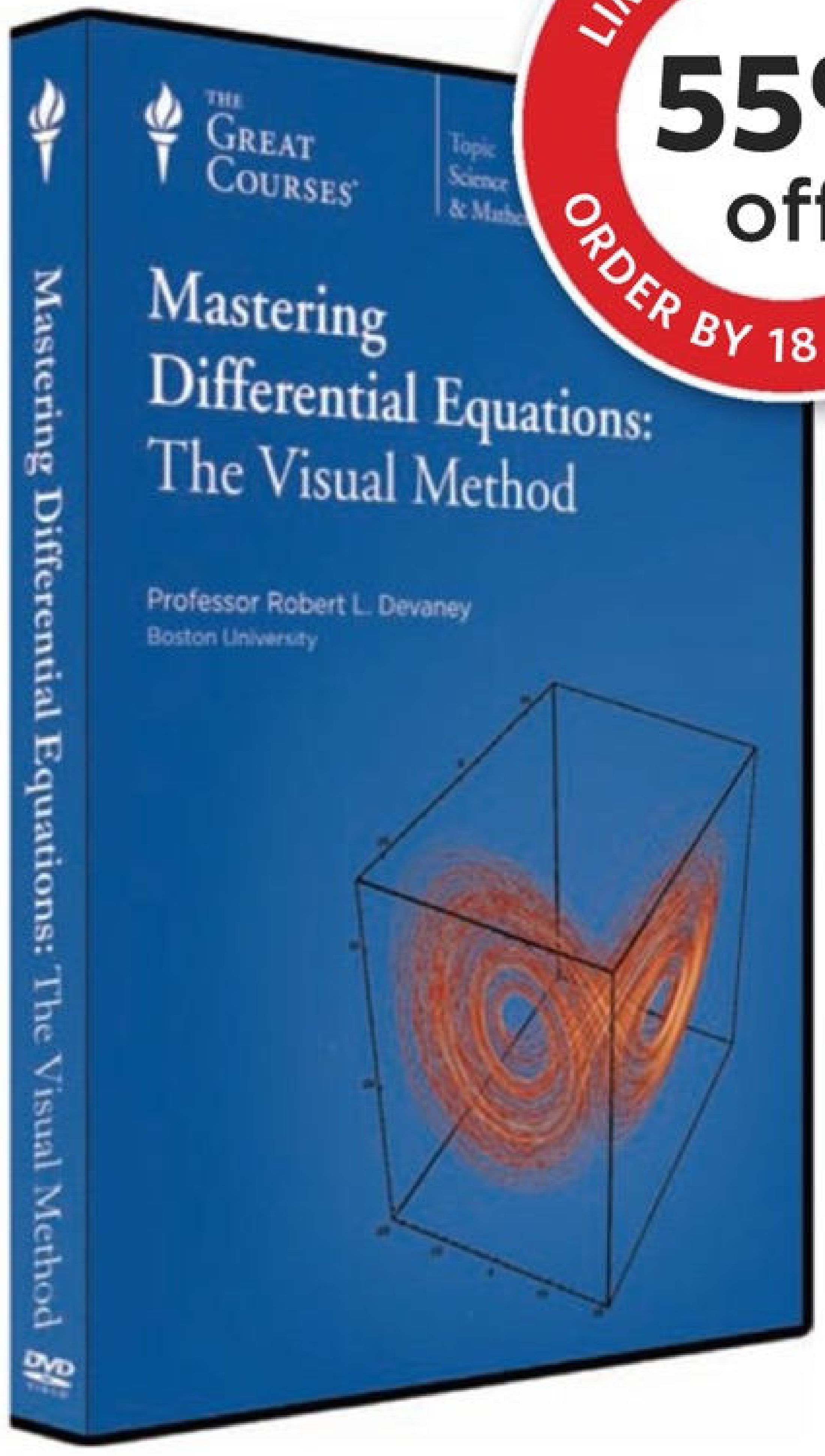
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5. Methods for Finding Explicit Solutions
6. How Computers Solve Differential Equations
7. Systems of Equations—A Predator-Prey System
8. Second-Order Equations—The Mass-Spring System
9. Damped and Undamped Harmonic Oscillators
10. Beating Modes and Resonance of Oscillators
11. Linear Systems of Differential Equations
12. An Excursion into Linear Algebra
13. Visualising Complex and Zero Eigenvalues
14. Summarising All Possible Linear Solutions
15. Nonlinear Systems Viewed Globally—Nullclines
16. Nonlinear Systems near Equilibria—Linearisation
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ULTIMATE TEST

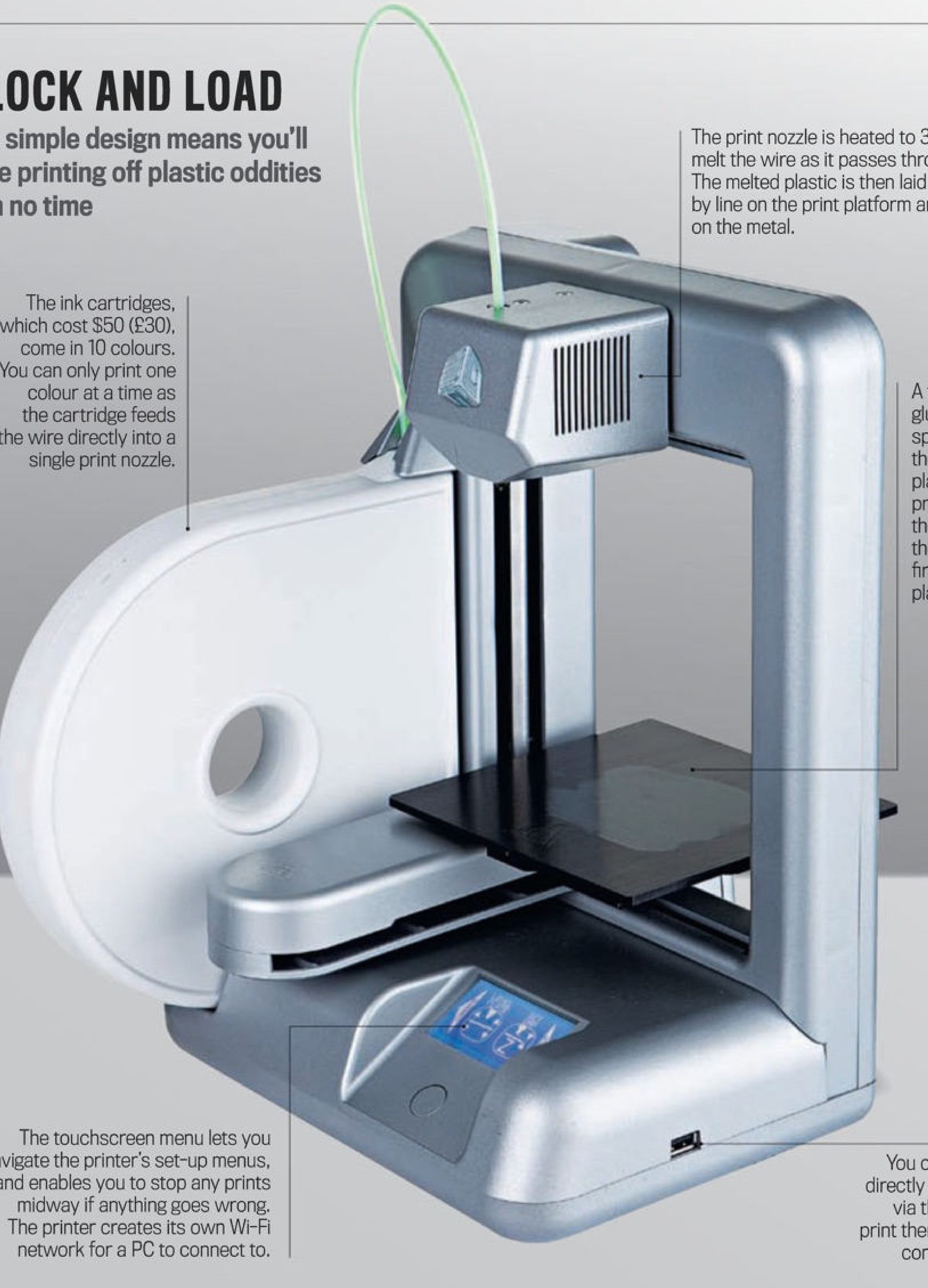
THE DREAM FACTORY

This is the Cube, the world's first home 3D printer that turns your ideas into reality. It takes five minutes to set up and costs just over £800, but should you buy one? **Daniel Bennett** tries it out

PHOTO: STUDIO4PHOTO.CO.UK

LOCK AND LOAD

A simple design means you'll be printing off plastic oddities in no time



The print nozzle is heated to 300°C to melt the wire as it passes through it. The melted plastic is then laid down line by line on the print platform and dries on the metal.

The ink cartridges, which cost $50 (£30), come in 10 colours. You can only print one colour at a time as the cartridge feeds the wire directly into a single print nozzle.

A thin layer of glue needs to be spread across the metal print plate before printing. It makes the first lines of the model stick firmly to the platform.

The touchscreen menu lets you navigate the printer's set-up menus, and enables you to stop any prints midway if anything goes wrong. The printer creates its own Wi-Fi network for a PC to connect to.

You can load designs directly onto the printer via the USB slot and print them without being connected to a PC.

WHAT DO BURRITOS, bicycles and blood vessels have in common? In the last year they've all have been made from scratch by a 3D printer. It's a dream technology. By adding one particle of a material to the next, a 3D printer can create a structure that otherwise would have been impossible, or at least prohibitively expensive to make. In the last few years it's enabled engineers to build lighter, stronger wings, architects to dream up innovative buildings and doctors to create better prosthetics for amputees. And this is just a taste of the benefits of 3D printing.

In the same way that computers moved out of university labs and into our living rooms, 3D printing is now trying to make its way into the home. Unfortunately, the 3D printers on sale until now have been ugly, tricky-to-assemble models that belong in the shed. But the Cube, with its matt-silver finish, touchscreen interface and relatively small size, is a different prospect altogether.

Plastic fantastic

In contrast to the likes of the build-it-yourself MakerBot Replicator, it's a breeze to set up. Pulling it out of the box, plugging in the power and connecting it to a PC (Macs aren't supported yet) via Wi-Fi took all of five minutes. Slotting the cartridge – a cassette that contains a thin wire of common ABS plastic – into place took less time than replacing a paper printer ink cartridge. Downloading the necessary software was even quicker.

In fact, setup was so hassle-free that I forgot one crucial ingredient: something to print. Surprisingly, with a virtual universe of items to print from sites like Thingiverse.com and the Cube's own site, Cubify.com, there was a dearth of anything that felt worthy enough to be the first virtual item I brought into the physical world. It would, after all, be like asking the replicator from *Star Trek* to make a cup of Earl Grey tea. A waste. After sifting through pages of dollhouse furniture, models of *Star Wars* characters and jewellery, I came across something I actually needed: eggcups. My previous set had fallen victim to a recent house move.

I found a rather fetching design, selflessly uploaded for free by Thingiverse user Fabricatis, and five seconds later it was downloaded and loaded onto Cubify's software client.

The program offers up a user-friendly interface that takes you through a step-by-step process that prepares the 3D model for the printer, letting you adjust the design as you see fit. Want to eat Ostrich eggs? Simply notch up the scale by 100 per cent – though you're limited by the size of the print platform, which caters for a volume of 14x14x14cm. You can also change the orientation and give the design the once over before printing. With more complex models, perhaps with overhanging segments, the printer will add the necessary scaffolding pieces to build it, which you can then snap away later.

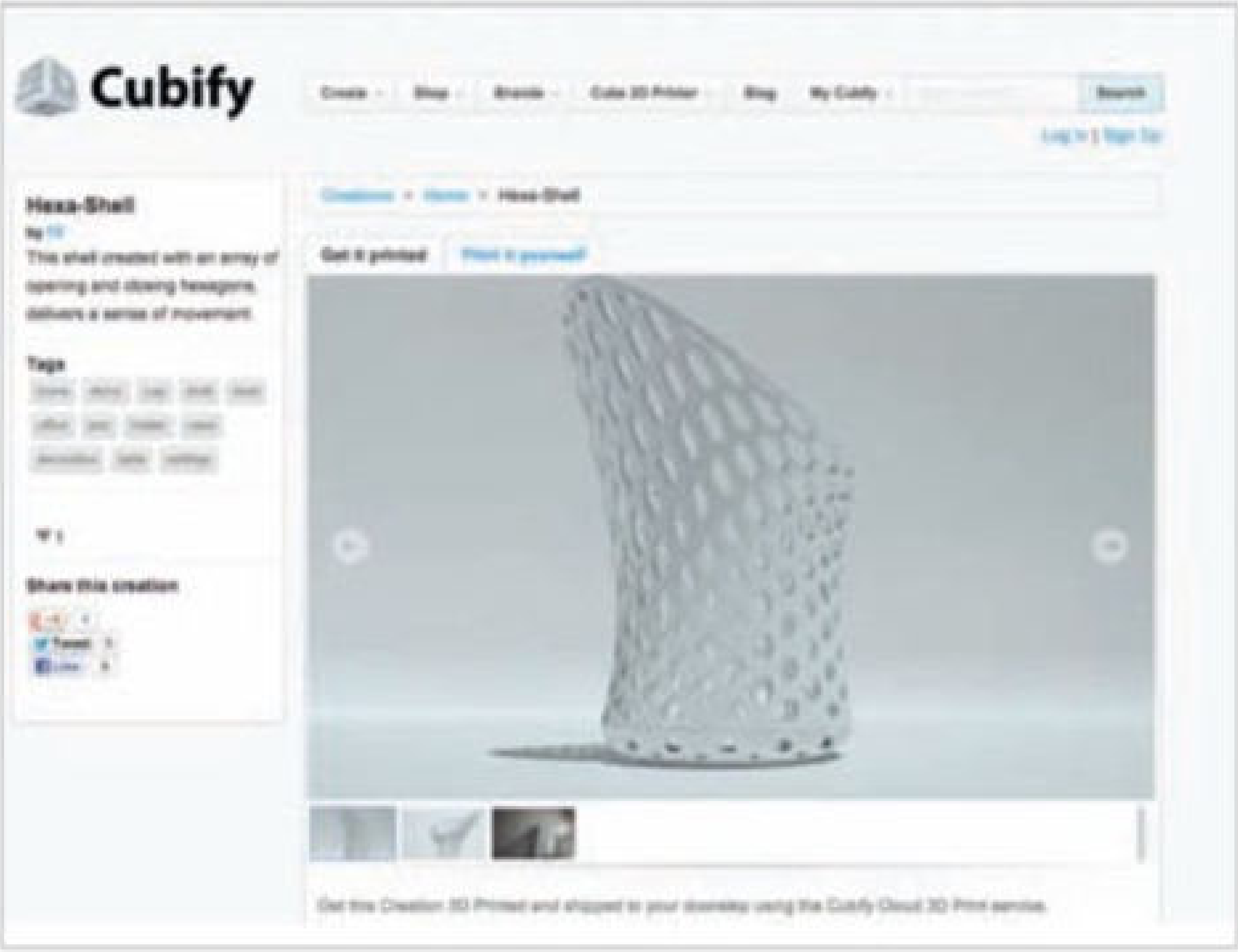
If you're technically minded, creating your own designs is an option too with Cubify's design software Invent, which costs an additional $49 (£31). Or you could use Google's free, but more basic, SketchUp program to make your own models.

All in all, grabbing a design off the internet and sending it to the printer was a remarkably easy process, especially considering how many wasted hours I've spent cursing at the office printer.

This is all a prelude to the main event, of course. Once the design

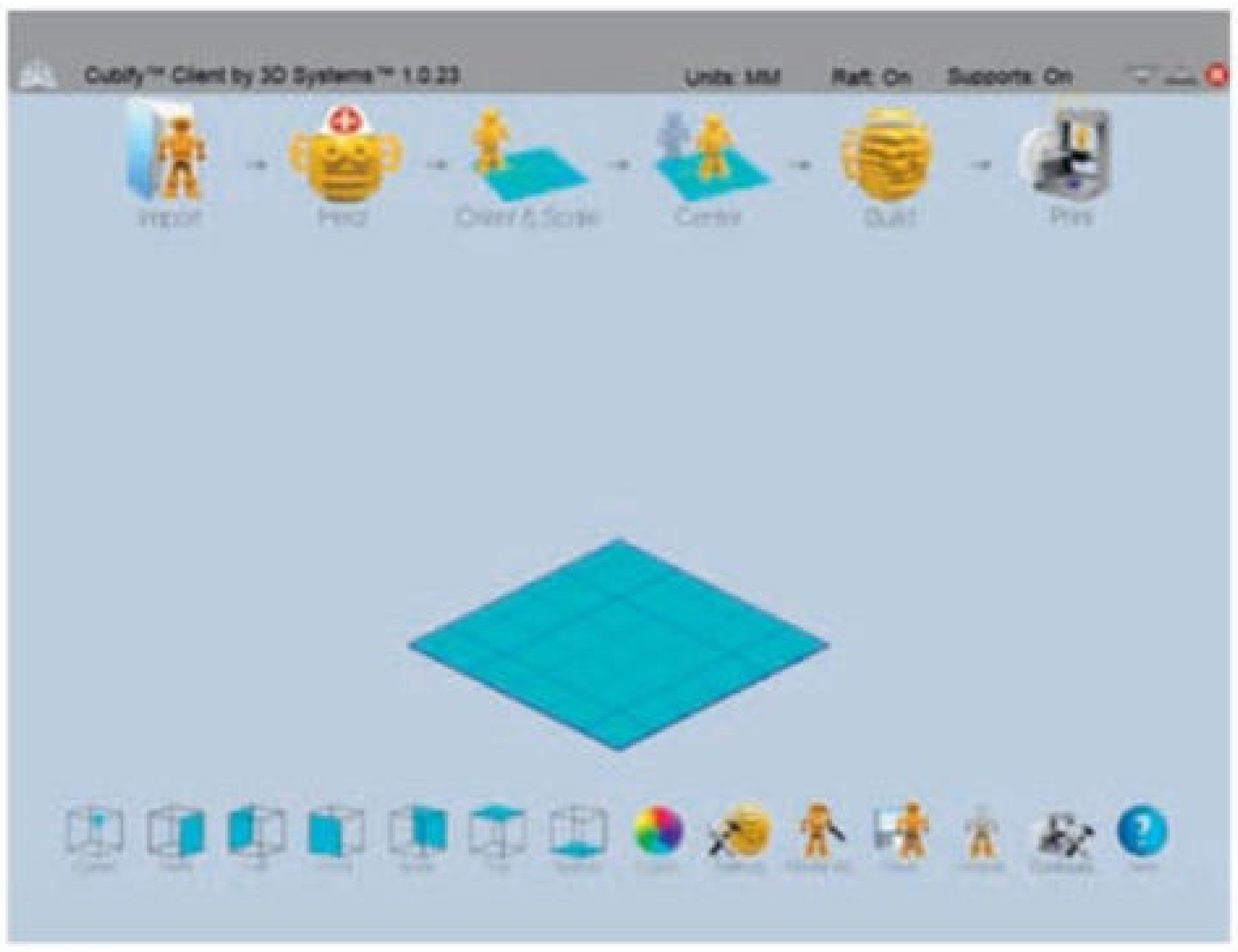
PHOTO: STUDIO4PHOTO.CO.UK

FOUR STEPS TO MAKE THE VIRTUAL A REALITY



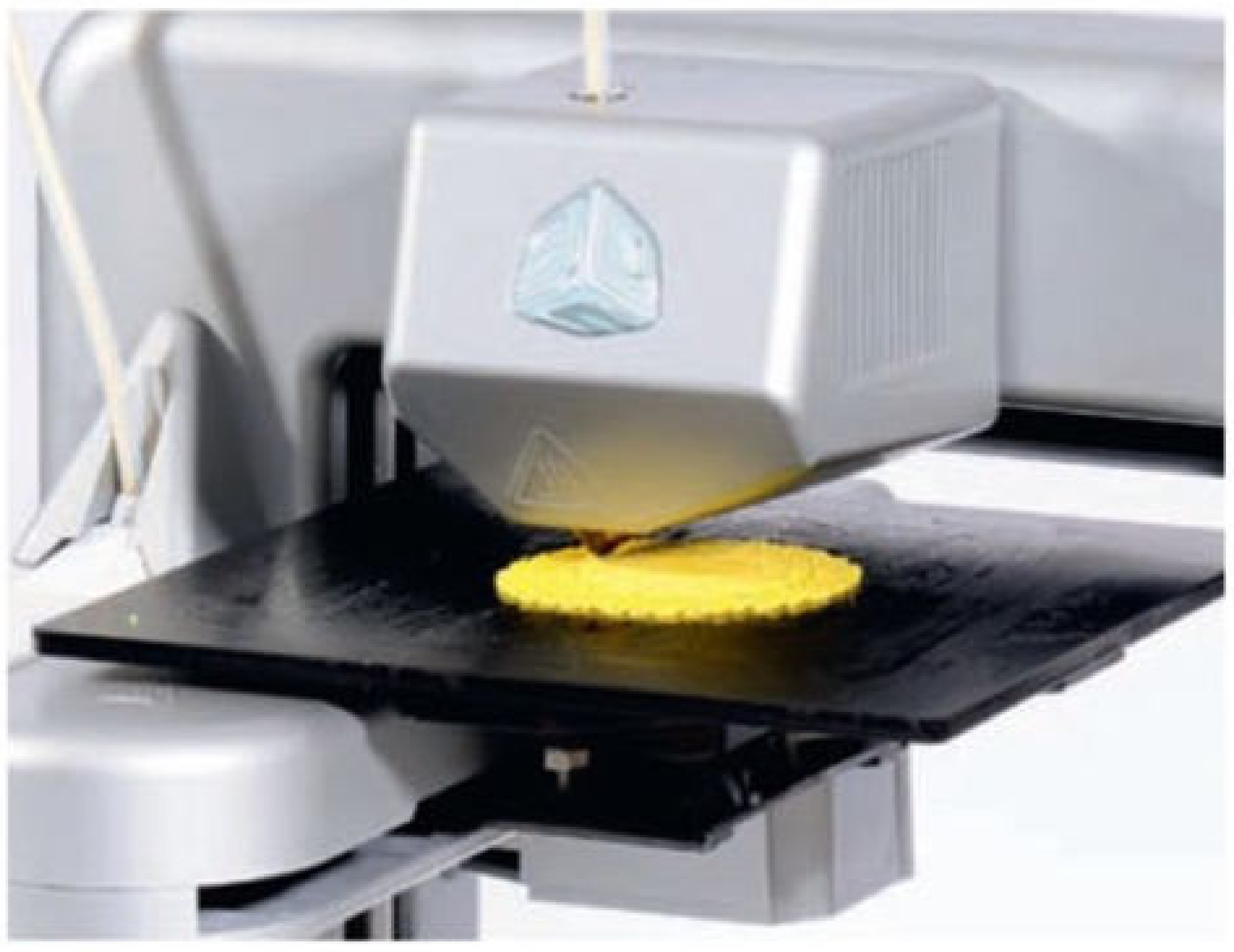
1. Search for a design

Hundreds of models that you can print are available at the Cube's own site, Cubify.com. Or for a wider selection of 3D items that aren't specifically designed to be printed on the Cube (but will work), visit Thingiverse.com. They'll download as .STL files, which will then be converted by the Cubify software into .CUBE files.



2. Convert and build

First load your design into the program. Then adjust its scale or orientation. There's a 'heal' button that will address any areas that are beyond the printer's capabilities. The 'build' button then creates the set of instructions needed to create the item – at this point it will work out any support structures not included in the design needed to build the model. Then hit 'Print'!



3. Glue and begin

The printer comes with a special glue that needs to be spread on the print platform in a thin layer. This enables the melted plastic to stick to the metal plate. The printer then lays down your design line by line. Instead of making everything solid, each design is hollow with a grid-like structure filling the gaps, making efficient use of the plastic-loaded cartridges.

4. Time to cool off

The design, like the vase shown here, is built up by laying melted plastic down on top of the stuff that's had a few seconds to cool and solidify. Once the printer is finished the metal plate descends and will need 10 minutes to cool down before it can be touched. The touchscreen then tells you when it's safe to snap the finished article off the platform.

HOT OFF THE PRESS

We churned out these Cube-made wonders

Creation 1 EGGCUP
This essential household item took just over two hours to print. Its lightness took us by surprise and was so good we made another to match.

Creation 2 ROCKET
Cubify.com has an app that lets you design your own spaceship. The big kid in us couldn't wait – so we shrunk it by 50 per cent to print it in a fraction of the time.

Creation 3 VASE
Taken from Thingiverse, this provided a more complex structure to test out. It faltered slightly with the lattice, filling in spaces that were meant to be holes.

was 'built', it's sent over to the printer. Two hours and 15 minutes was the estimated print time. It seemed like a long while to wait for an eggcup, but it's infinitely shorter than ordering one from the internet and waiting for the post, not to mention kinder to the environment.

Once the Cube had heated the print nozzle to 300°C, the magic began. The ABS plastic wire is fed through the heated funnel and laid down according to the design's instructions. Line by line the base began to form. Rather than filling in the entire model, it saved on ink (and weight) by making the eggcup hollow. In between the inner and outer edges of the cup it built a grid support structure that kept everything strong but light. Watching the printer whirr away was surprisingly captivating.

The finished article

The end result? A resounding success. As with any new technology I expected teething problems, but this didn't happen, even after several prints. The eggcup was followed by some toy figurines, and a personalised key ring. As I started to stretch its capabilities, with a small vase made out of a lattice structure, it faltered a little, creating some imperfections, though nothing we couldn't snap off.

But the list of items we printed hints at the reason 3D printers won't take off just yet. There's absolutely no need for any of them. That's not to say there isn't anything useful out there. There are hundreds of models for crucial spare parts, from washing machines clips to light fixtures. But there's nothing you can make yet that will tempt someone to part with £800. For now, the Cube is still strictly for enthusiasts.

Despite this, the Cube is a remarkable product. It's a pivotal first step in the technology's history and one we're sure to look upon fondly when the 3D printing revolution makes its way into everybody's home. ■

The Cube
Price: $1,299 (£818) plus P&P, cartridges cost $50 (£31)
Info: Cubify.com

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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL

SUSAN BLACKMORE

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester

ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service

LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus* Q&A, Tower House, Fairfax Street, Bristol, BS1 3BN

The Space Shuttle Enterprise wasn't the ideal way to get through New York's rush hour

Q **SARAH LUND** IPAD APP

What happened to the Space Shuttles?

A THEY ARE ALL in museums. Aerospace museums in New York, Virginia, Florida and Los Angeles were each chosen to receive one of the retired Shuttles and the Museum of Flight in Seattle was given a wingless Shuttle that never flew, but which was used for astronaut training. There is also a full scale, highly accurate model of the Shuttle, called Explorer, at the Johnson Space Centre in Houston, while a wood-and-steel mock-up of a Shuttle called Pathfinder that was used to test road clearances and crane capabilities, now resides in a museum in Alabama. **LV**

PHOTO: GETTY

Q **RON CLARKE** HEREFORD

How do USB flash drives hold so much data?

Flash drives, thumb drives, pen drives… whatever they're called they store a lot of data

A FLASH STORAGE DEVICES are based on chip technology called Electronically Erasable Programmable Read Only Memory (EEPROM). USB flash sticks use a refined version of EEPROM. In its earliest incarnation, individual bits of data on the chip had to be erased separately. It was like a vertically stacked library where getting at one book at the bottom of a pile meant having to move the books above it one at a time. But now multiple memory cells can be addressed simultaneously, allowing entire blocks to be written and rewritten in one go, like moving a pile of books, rather than one book, at a time. It requires considerable on-chip processing and is a feat that has come about through recent advances in chip design and miniaturisation, ushering in USB drives capable of storing gigabytes of data. **GM**

In Numbers

100,000

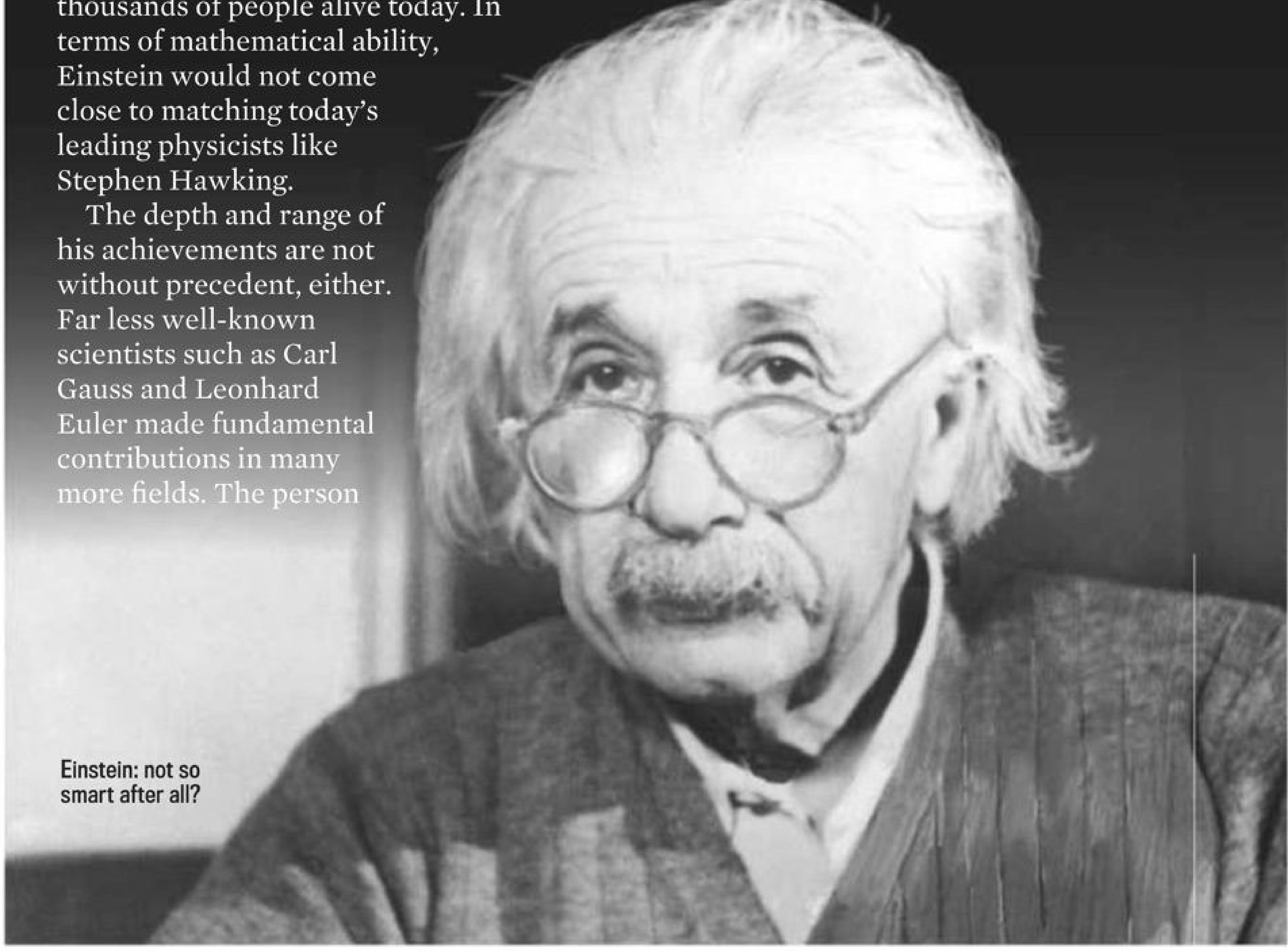
kilometres (62,000 miles) is the total length of blood vessels in the human body

Q **DYLAN RITCHIE** BY EMAIL

Is Einstein the smartest person who has ever lived?

A EINSTEIN HAS BECOME synonymous with brilliance, and he's certainly one of the greatest scientists of all time. But it's hard to claim he's the smartest person who ever lived. It's often said (with scant evidence) that his IQ was 160; even if true, that would make him less intelligent than thousands of people alive today. In terms of mathematical ability, Einstein would not come close to matching today's leading physicists like Stephen Hawking.

The depth and range of his achievements are not without precedent, either. Far less well-known scientists such as Carl Gauss and Leonhard Euler made fundamental contributions in many more fields. The person with perhaps the strongest claim to being the smartest person of all time is the Victorian polymath Sir Francis Galton, whose work on everything from statistics and evolution to the 'wisdom of crowds' is still used every day by researchers a century after his death. **RM**



Einstein: not so smart after all?

Q **MIKE ROBBINS** CHESHIRE

How do safety matches work?

A THE 'STRIKE ANYWHERE' variety of match is basically Armstrong's mixture. This is an explosive made of red phosphorus, with potassium chlorate as an oxidiser. Armstrong's mixture is so reactive that even a small bump will set it off (very small amounts are used in the paper caps for toy guns), so matches have various binders and fillers added to stop the box igniting when you shake it.

Matches coated with Armstrong's mixture can be set off by even a slight bump

But still, the friction of the match head against sandpaper or another rough surface is enough to trigger the reaction. Safety matches work by separating the two main ingredients. The red phosphorus is on the striking surface of the box, while the match head contains the potassium chlorate. When they are rubbed together, the friction causes a tiny reaction at the point of contact and after that, sulphur and starch in the match head burn to sustain the flame. **LV**

PHOTO: THINKSTOCK X2, PRESS ASSOCIATION, ALAMY, SUPERSTOCK

QUESTION OF THE MONTH

WINNER!
Alex wins a copy of *Big Questions From Little People* by Gemma Elwin Harris (Faber and Faber, £12.99)

ALEX SUMMERS BRISTOL

Does a full e-book weigh more than an empty one?

A YOUR INSTINCT WOULD be to say no. Electrons have mass, but when they're used to store data, only their arrangement changes. The number of electrons remains the same. However, the University of California, Berkeley professor John Kubiatowicz refers to the way that electrons are trapped through a mechanism called tunnelling. Each cell of memory in an e-book contains two gates separated by an oxide layer. When data is stored a charge is applied, unleashing a torrent of electrons flowing from one side of the layer to the other, where they remain lodged until another charge is applied. Being trapped increases the electrons' energy. From Einstein's $E=mc^2$ in which energy and mass are equivalent, the e-book becomes slightly heavier.

A full Kindle would be an un-measurable billionth of a billionth of a gramme heavier than a brand new one. **GM**

E-readers have replaced heavy tomes, but are they heavier when full?

MEL JEFFRIES CRANLEIGH

How do we pick out faces in a crowd?

A SCIENTISTS AT BIELEFELD University, Germany, asked subjects to search for faces within crowds of people with neutral expressions. They found subjects were twice as quick at picking out faces with open mouths and visible teeth. So next time you're trying to attract attention in a crowd, try laughing. **RM**

JOHN WIGGIN LUTTERWORTH

Why would rose-tinted glasses make you happy?

A ROSE-COLOURED LENSES filter out the blue part of the spectrum. Blue light has a shorter wavelength than red and focuses slightly to the front of the retina. Removing blue light improves contrast overall. This might make it easier to process a wide field of view. Research at the University of Toronto has suggested that a wide attentional field is associated with positive moods. **LV**

DAVID PRYCE MORRIS BY EMAIL

Why do we have earlobes?

A EARLOBES HAVE A good blood supply and may help keep the ear warm. But it could be that natural selection simply hasn't eliminated them yet. There is also some evidence that we find earlobes attractive, and therefore favour them when choosing partners. **LV**

TOP TEN

LONGEST RIVERS

6,727km
(4,180 miles)
Nile Starts at Lake Victoria, Africa, and ends in the Mediterranean Sea

6,296km
(3,912 miles)
Amazon Its source is glacier-fed lakes in Peru; runs into the Atlantic

6,276km
(3,900 miles)
Yangtze Trickles from Tibet before emptying into the East China Sea

5,970km
(3,710 miles)
Mississippi Starts at Lake Itasca, USA and runs into the Gulf of Mexico

5,567km
(3,459 miles)
Ob Source: Altai Mountains, Russia; mouth: Gulf of Ob

4,667km
(2,900 miles)
Yellow Flowing from the Kunlan range, China, it has yellow, muddy waters

4,506km
(2,800 miles)
Yenisei Starts in the Tannu-Ola range, Russia, ends in the Arctic Ocean

4,498km
(2,795 miles)
Paraná Runs through Brazil, Paraguay and Argentina

4,438km
(2,758 miles)
Irtysh Starts in the Altai range, Russia, and ends when it joins the Ob River

4,370km
(2,716 miles)
Zaire Flows through the Congo and runs into the Atlantic Ocean

Q **KATE WRIGHT** CANTERBURY

Why did humans lose the ability to make vitamin C?

A ALMOST ALL ANIMALS and plants make their own vitamin C, or ascorbic acid. The exceptions are some birds and fish that lack the crucial enzyme for making it, and just a few mammals: guinea pigs, bats and some primates, including humans. The mutation responsible probably occurred about 25 million years ago. One theory is that our primate ancestors had a diet so rich in vitamin C that they could save energy by not making it themselves. Another claims that this change actually accelerated the evolution of higher primates: vitamin C protects DNA from damage; so not making it increased the mutation rate. We don't get enough if we don't eat enough raw meat, offal, green vegetables or citrus fruits. Without it we can't make collagen, our connective tissues and blood vessels break down and teeth fall out. **SB**

Crystals of ascorbic acid: eat it to prevent your body falling apart

Q **JULIA VELLA** MALTA

Do stars spin on an axis like planets?

The star Regulus rotates so quickly that it bulges out in the middle

A STELLAR ROTATION IS usually the result of the rotation in the gas cloud that condensed to form the star. However, unlike planets, stars are not solid bodies, so their rotation is not always simple. Firstly, just like many planets, stars have equatorial bulges. The faster the rotation, the more pronounced the bulge. The star Regulus, for example, rotates at about 320km/s and its equatorial radius is about a third larger than its polar radius.

Many stars also show differential rotation, whereby the rotation rate is highest at the equator but decreases as latitude increases. For example, at the equator the Sun rotates once in about 25 days, but at the poles each rotation takes more than 34 days. This effect generates the magnetic fields of many stars. Pulsars, which are the magnetised remnants of exploded stars, rotate extremely quickly – the fastest yet found turns 716 times every second! **AG**

PHOTO: SCIENCE PHOTO LIBRARY X3, GETTY X2, THINKSTOCK

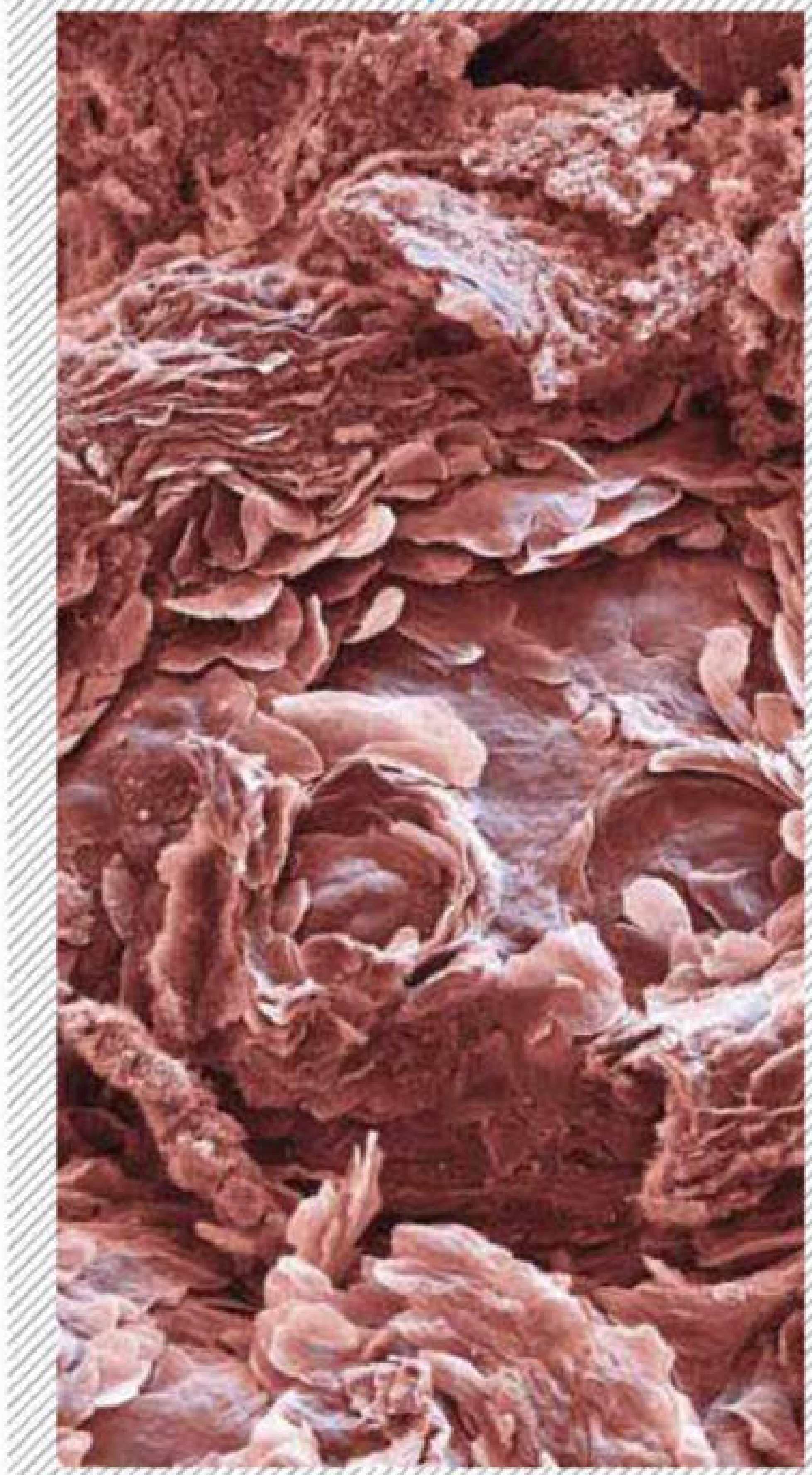
Q **AMANDA DAVIES** KINGS LYNN

What's the upper limit on how fast someone can talk?

A THE CURRENT RECORD, in English at least, is 637 words per minute, a record held by English comedian and presenter Steve Woodmore. That's about four times faster than most people talk and twice as fast as we can read. The practical limit on speech is comprehension. Beyond 300 words per minute, you can't really make out the individual words clearly – record attempts are adjudicated by recording the speech and playing it back more slowly.

The theoretical upper limit on speed would be the rate at which the facial muscles can contract. Muscle fibres can't contract faster than about five times per second, so if you are repeating the mouth-stretching words "wow oh wow oh", your lips couldn't manage to open and close more than 300 times per minute. Alternating between different muscles might let you interleave more words but 637 definitely looks like it's quite close to the natural limit. **LV**

WHAT IS THIS?

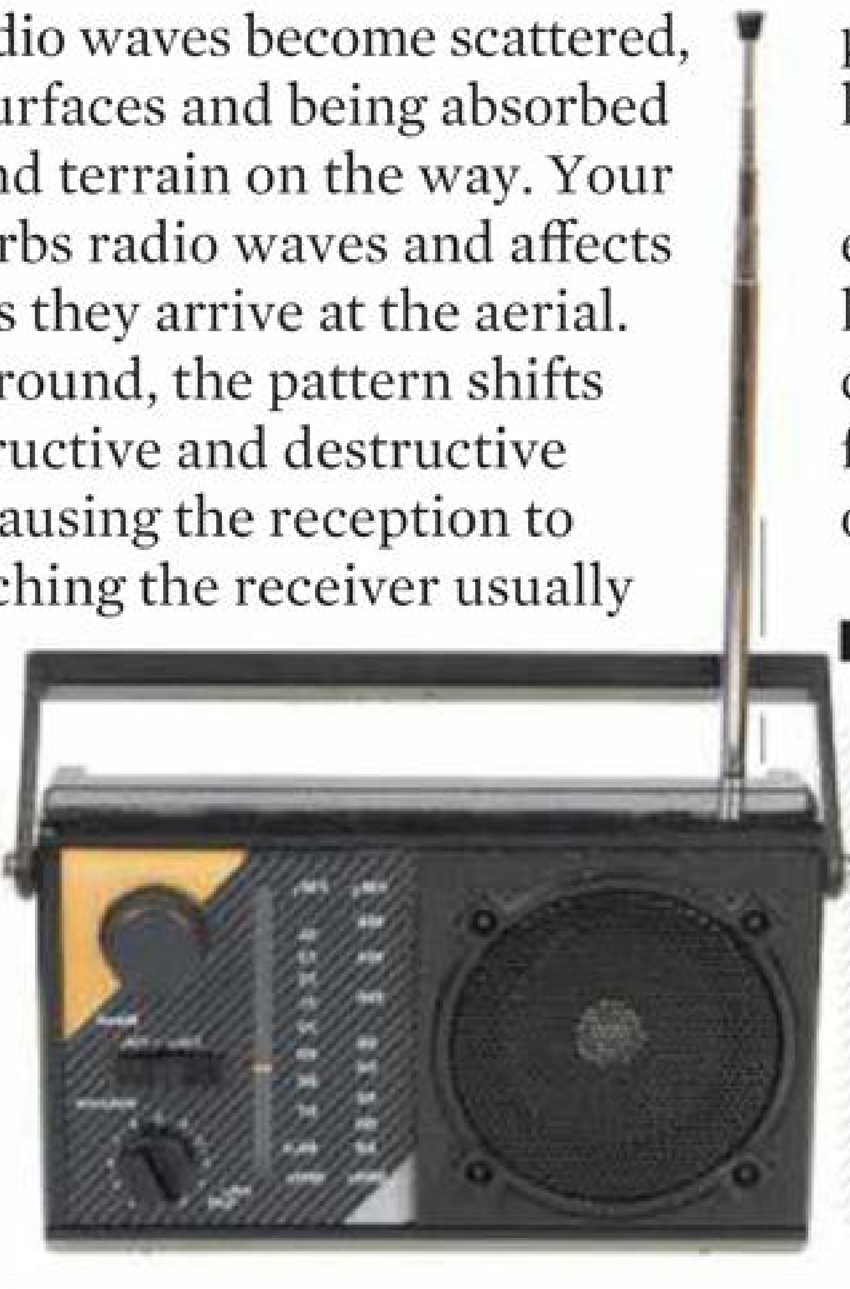


KNOW THE ANSWER?
Go to **sciencefocus.com/qanda/what** and submit your answer now.

Q **SHAUNA O'NEILL** ROSCOMMON

Why does standing near a radio improve reception?

A IN AN AREA with poor reception, a radio struggles to separate the useful signal from the electromagnetic noise. Between the radio and the distant transmitter, radio waves become scattered, bouncing off surfaces and being absorbed by buildings and terrain on the way. Your body also absorbs radio waves and affects their pattern as they arrive at the aerial. As you move around, the pattern shifts through constructive and destructive interference, causing the reception to fluctuate. Touching the receiver usually helps the reception, because absorbing all those waves makes you a surprisingly effective antennae. **GM**



Q **ANTHONY WYVILL** HARROGATE

Why are nut allergies so common?

A POSSIBLY BECAUSE MOST people now eat far more nuts and peanuts (which are not true nuts but legumes) than they used to. There is a genetic basis to many allergies, but some have to be primed before they have any real effect. One theory is that mothers in developed countries are now eating more nuts and peanuts when they are pregnant. This means their babies are primed for the allergy even before they are born.

Another suggestion is that with concerns over exposure to the Sun, parents are now applying far more moisturising creams and lotions to their babies. These often contain low-grade peanut oil which might then prime the allergy. It might explain the association between eczema and peanut allergy in children, because such lotions are applied to soothe the itching.

However, some research shows that early exposure to peanuts can prevent later allergic reactions. Children in countries where lots of nuts are eaten from infancy do not show the high levels of allergy common in Western countries. **SB**

? Did you know?

A hospital in Northern Ireland has become the first in the UK to use a telepresence robot. Dr Charles McAllister used the robot at Daisy Hill Hospital to interact with patients from over 32km (20 miles) away.

Q **VICKY ANDREWS** BRIGHTON

Why does a sneeze feel nice and a cough doesn't?

Get your kicks by sneezing; coughing is simply an annoying sound for those around you

A SNEEZING IS a contraction of lots of muscles at once. As they all clench you feel a build up of tension that would be uncomfortable if it persisted, but it's over in a fraction of a second and the contrast of the sudden release feels great. A coughing fit can be similar, but there isn't the same build up; it's more protracted. A sneeze also nearly always cures the tickle that triggered it, whereas coughing can worsen things. **LV**

Q **ANDREW MITCHELL** LONDON

Why does the Moon affect Earth's tides more than the Sun?

A THE TIDES ARE the result of the difference between the forces of gravity on opposite sides of the Earth. Because the Earth's diameter is such a small fraction of the Sun-Earth distance, the Sun's gravitational pull changes by only 0.017 per cent across the Earth. But for the Moon, that difference is 6.8 per cent, 400 times greater. If you factor in the overall stronger pull from the Sun, this means the Sun's tidal effect is only about 44 per cent that of the Moon. **AG**

The Moon maintains its hold on the tides despite being smaller than the Sun

In Numbers

740

is the number of new stars that the enormous Phoenix galaxy cluster has been found to churn out each year

Q **TIM JOHNSON** DEVON

When will the Milky Way and Andromeda collide?

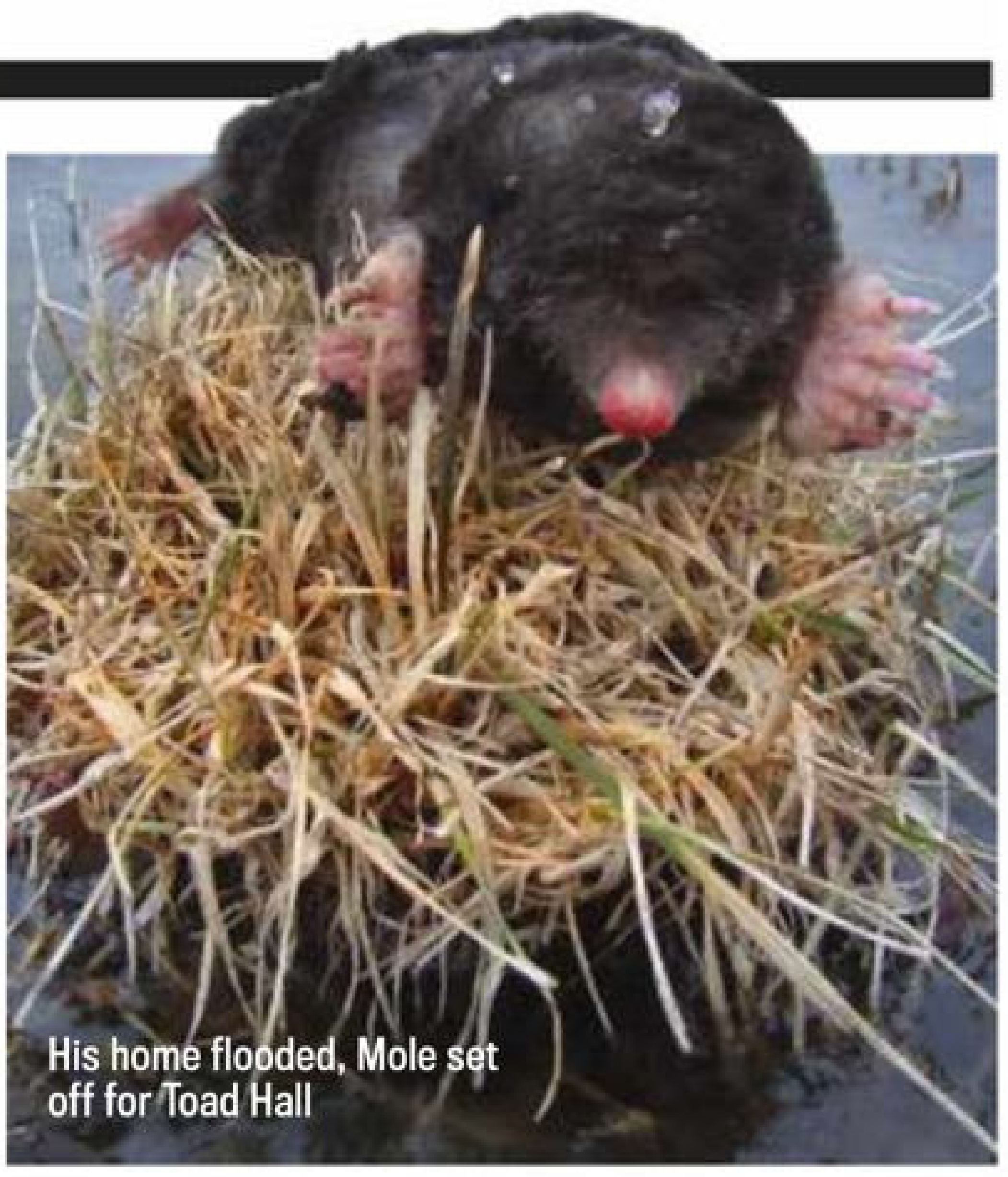
'Milkomeda' could become the name of our home galaxy in 4 billion years' time

A IT HAS BEEN known for decades that our closest large galactic neighbour, the Andromeda Galaxy, is heading toward our own Milky Way at around 120km/s. But until recently, astronomers were unsure whether Andromeda would score a direct hit, a near miss or a glancing blow. While it's quite easy to measure the relative approach speed of Andromeda, it's very difficult to measure its exact direction of motion. But a few months ago, using the Hubble Space Telescope, astronomers finally pinned down its trajectory. It will collide head-on with the Milky Way, in about four billion years' time. **AG**

Q **RON BARNES** NORFOLK

What happens to moles during flooding?

A YOU'D HOPE THAT when a river bursts its banks and floods the surrounding fields that the moles are able to escape quickly enough to find dry ground. However, this is unlikely as their fate depends on how quickly their tunnels flood. When a river bursts its banks and the flooding is deep and sudden then they simply drown inside their own homes. **SB**



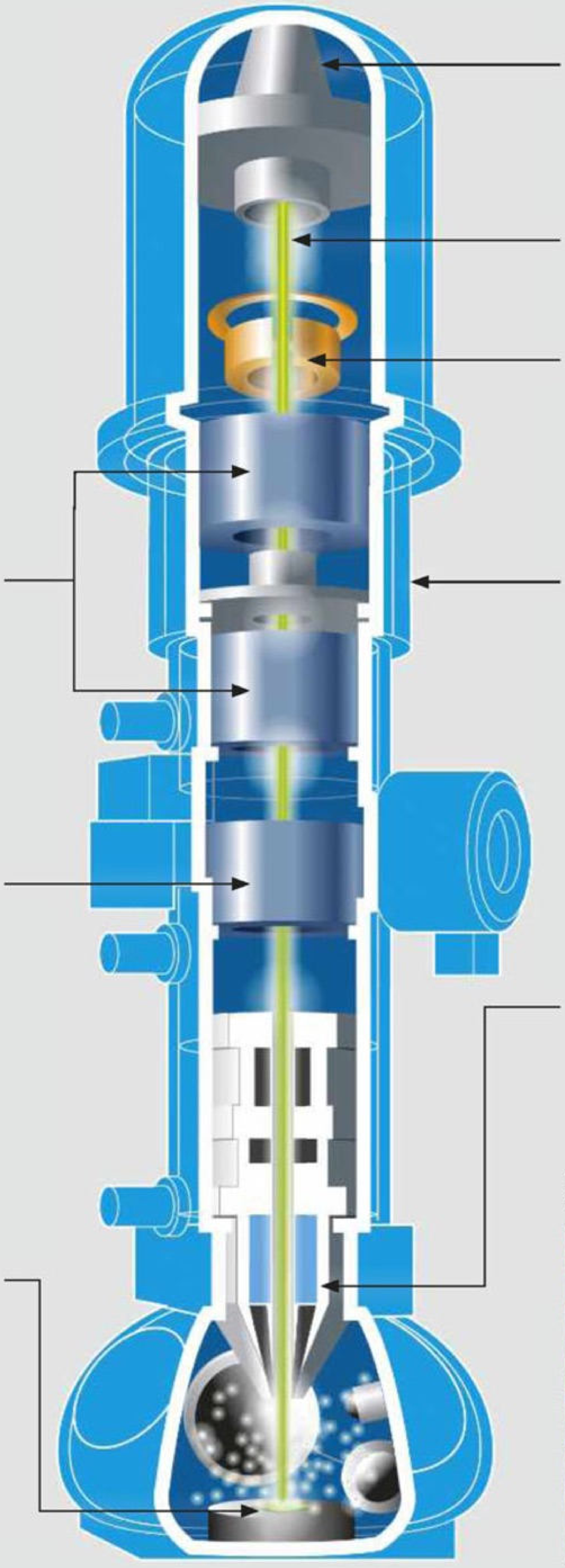
His home flooded, Mole set off for Toad Hall

PHOTO: NASA, CATERS NEWS, THINKSTOCK X2, ILLUSTRATION BY PAUL WESTON

HOW IT WORKS

SCANNING ELECTRON MICROSCOPE

BACTERIA CAN APPEAR like a swarm of menacing creatures and the surface of skin a rugged landscape – images from a scanning electron microscope deliver incredibly detailed views of very small things. By firing a beam of electrons at a target, scientists can observe smaller objects than it's possible to see with an optical microscope, which is limited by the wavelength of light. They have been used to study a wide range of materials, and have helped scientists examine the structure of drugs to make them more effective.



ELECTRON GUN
Acting as an electron gun, a tungsten filament is heated, which emits negatively charged electrons.

BEAM
The beam is typically 0.4 to 5nm in diameter – a nanometre is one-billionth of a metre.

ANODE
A positively charged anode attracts the negatively charged electrons down the microscope. They pass through the middle of the anode as a beam.

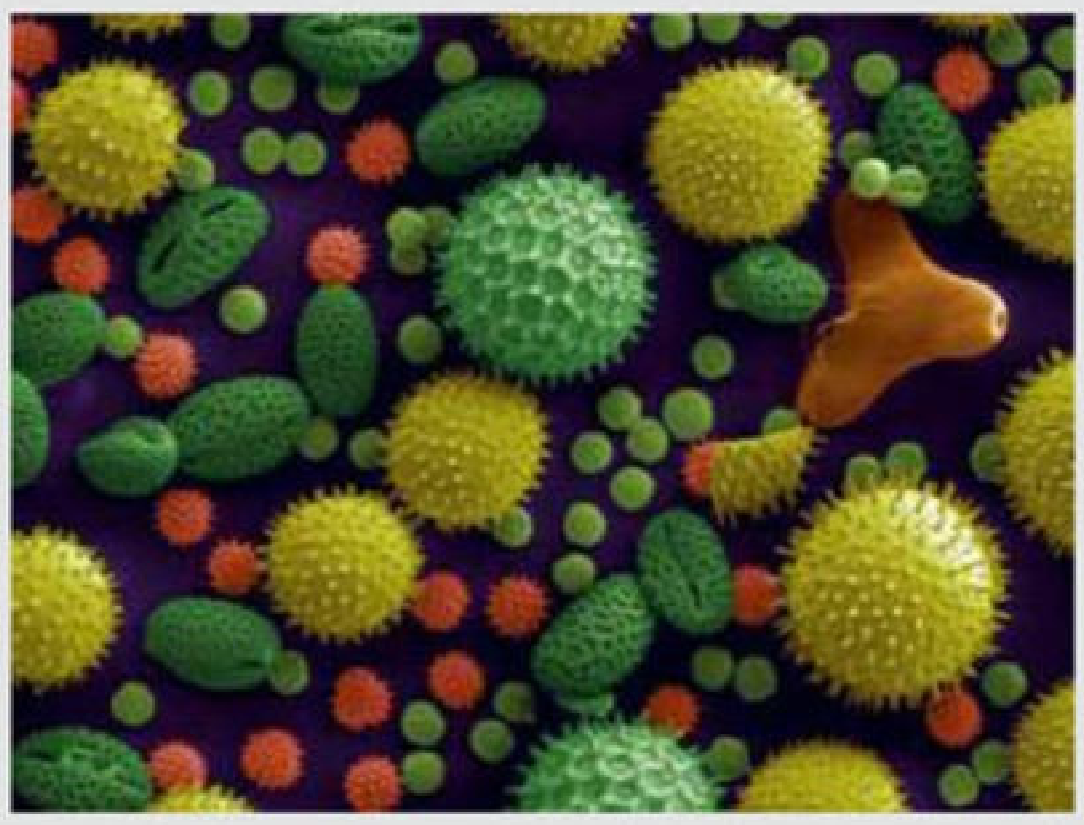
CONDENSER RINGS
Electromagnets known as condenser rings keep the beam focused ensuring a maximum number of electrons hit the target.

VACUUM
The whole apparatus is held in a vacuum to ensure the focused electron beam faces no interference from other particles.

SCANNING COILS
These create a fluctuating magnetic field that is able to move the electron beam back and forth over the target.

FOCUSING LENSES
A series of lenses focus the electron beam so that it is able to hit a tiny part of the sample.

SAMPLE
When the electrons reach the sample chamber they hit the target, knocking secondary atoms off it. A series of detectors pick up these secondary atoms and are able to discern the target's surface structure and composition. These include a CCD array that converts electrons striking a fluorescent plate into an image.



Placed under a scanning electron microscope, the intricate beauty of pollen grains is revealed

Q ED WILLIAMS LIVERPOOL

Why is front crawl the fastest stroke?

Doggy paddle will not win you a gold medal in the 100m freestyle

A THE BREASTSTROKE IS the slowest of the four competition strokes because the arms must return to the front by moving through the water, which creates some backwards thrust. The other three strokes all recover the arms through the air, but the front crawl also allows them to adopt a more efficient scooping angle in the water, compared with backstroke, because of the way our shoulder and elbow joints are arranged. Butterfly stroke loses some efficiency because more of the body needs to be raised out of the water to bring the arms forward and this means that less of the force is directed to forwards motion.

Because of the energy lost to turbulence at the surface, it is actually slightly faster to swim entirely underwater. But this is banned in competition swimming because of safety fears – swimmers must surface within 15m of the start of a turn. **LV**

Did you know?

Honda's Asimo is the fastest humanoid robot, able to run at 9km/h (5.6mph) with both feet leaving the ground.

The jury is still out on whether it's a good idea to get away from a sinking ship as fast as possible

Q NICK STRACHAN PRESTON

Do sinking ships really suck nearby objects down with them?

A IN THE EARLY 20th Century this was widely held to be the case, and the advice was for lifeboats launched from a sinking ship to row hard away to avoid being pulled down with it. This may have contributed to the loss of life on the Titanic, as only 13 survivors were pulled from the water. However, some survivors report struggling against a powerful suction, while others claim to have been able to step off the sinking ship without their head even going under.

There are two proposed mechanisms for the suction effect. The first is the slipstream. As the boat slides under the surface, it creates a current of water that flows down with it due to friction with the side of the hull and vortices created as the water closes up behind the boat. The second idea is that air trapped inside the ship is released as it sinks, in a stream of bubbles that lower the effective density of the surrounding water and reduce your buoyancy to the point where you sink. The bubble theory isn't well supported by evidence; in fact the rising bubbles generate a slipstream of their own that can actually push you upwards.

Whatever the cause, the effect seems to have been exaggerated. There are no reports of lifeboats being dragged under by a sinking ship, but in the case of a very large ship like the Titanic, the slipstream may have been enough to drag people down for a few metres. **LV**

Q JIM REEVES LEEDS

Could Earth be artificially cooled?

A ONE OBVIOUS WAY to offset the effects of global warming is to boost the Earth's albedo – its ability to reflect the Sun's heat back into space. Clouds, dust and other 'aerosols' like particles from volcanic eruptions do this naturally, Earlier this year, US-based aerospace company Aurora Flight Sciences claimed that using balloons to release millions of tonnes of sulphur dioxide into the stratosphere each year could cool the Earth by 1 to 2°C. One drawback is the cost, estimated at around $10 billion a year. However, there are potentially unintended consequences of trying to tweak the complex set of interactions that make up the Earth's climate. **RM**

A warming planet – should we step in to cool it artificially?

PHOTO: PRESS ASSOCIATION, CORBIS, THINKSTOCK

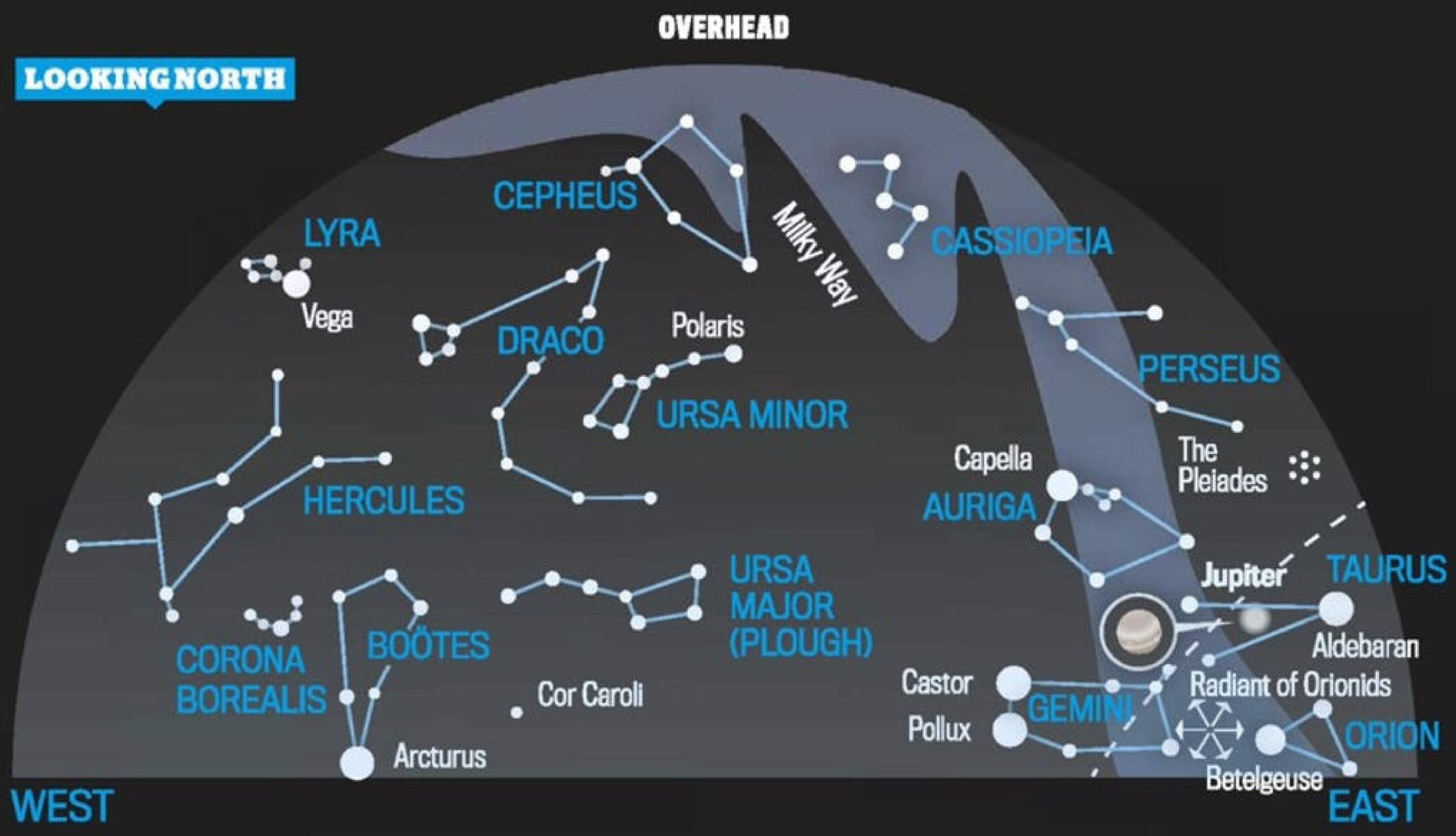
THE NIGHT SKY: WHAT CAN I SEE IN OCTOBER?

BBC ONE Don't miss *The Sky at Night* on BBC One every month www.bbc.co.uk/skyatnight

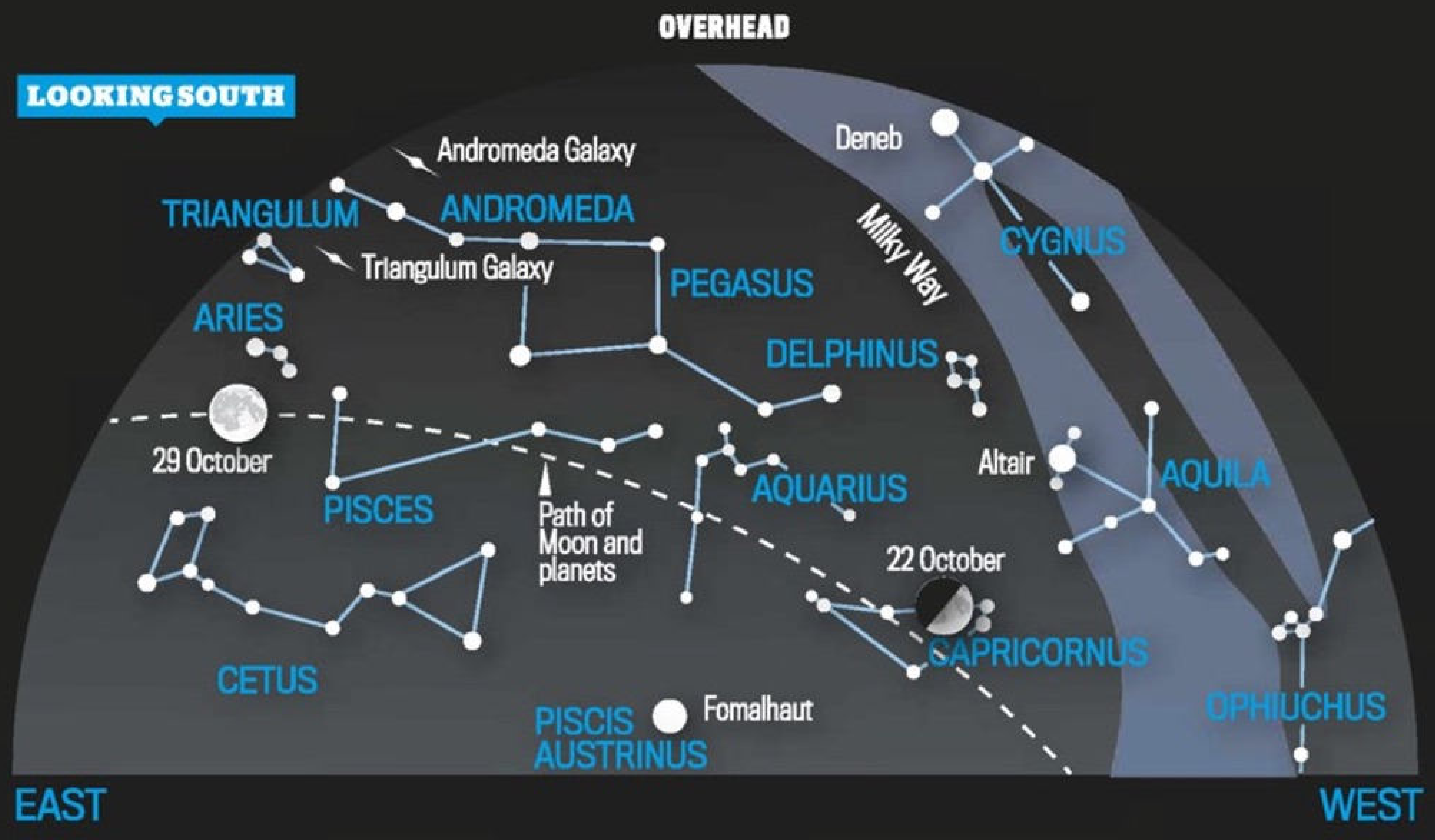
Astronomy with Heather Couper and Nigel Henbest

WELCOME TO OUR new-look night sky guide. The charts – looking north and south – give you a complete picture of what's on view. October is dominated by the constellation of Pegasus, trailing Andromeda, and there are plenty of gems to be found. What's more, now we're under autumn skies the nights are getting longer, so you can start observing earlier in the evening. Don't miss Jupiter making a welcome appearance with its family of moons and hopefully a fine display from the Orionid Meteor Shower if it's not too cloudy. Fingers crossed!

LOOKING NORTH



LOOKING SOUTH



LOOKING NORTH

5 October, 10pm
The Moon passes under brilliant Jupiter – a great sight if you've got binoculars or a small telescope. You'll spot Jupiter's four largest moons up close to our own.

20-21 October, after midnight
The Orionid Meteor Shower is putting on a show. The Moon sets at 10pm, so the skies will be dark. The shooting stars – fragments of Comet Halley – rain down at a rate of 20 meteors an hour.

All month, all night
The constellation of Cassiopeia is hugging the zenith of the sky. This W-shaped pattern of stars is home to two supernova remnants – relics of exploded stars.

LOOKING SOUTH

All month, all night
The Andromeda Galaxy is at its best. Our neighbouring spiral galaxy – which lies at a distance of 2.5 million light-years – is visible to the unaided eye.

All month, all night
Just below the Andromeda Galaxy is its smaller cousin: the Triangulum Galaxy. This ragged spiral is a hotbed of star formation. It's tricky to pick out, even with a small telescope.

All month, 10pm
The star Fomalhaut is low in the south over the constellation of Piscis Austrinus. Surrounded by dust and gas, it's started to give birth to planets – the first of which was detected by the Hubble telescope in 2008.

Find out more
Sky at Night Magazine
On sale now, priced £4.99

GEORGE BUTLER BY EMAIL

Why aren't airships used anymore?

EARLY AIRSHIPS COMPETED against steamships. They carried smaller loads, but were faster and could travel directly to inland cities. Aeroplanes, however, are much faster and can carry more, which offsets their higher fuel costs. Airships are also trickier to handle at take-off and landing. A few are still used for tourist flights and surveying. **LV**

So the opening credits of *Doctor Who* were scientifically accurate!

JOHN MEERS BY EMAIL

What would you see if you were travelling at the speed of light?

EINSTEIN ASKED HIMSELF this very question when he was 16, and his search for a solution led him to the Special Theory of Relativity. According to this, the speed of light is a universal constant, and thus the same for all observers. That, in turn, implies that lengths and time intervals aren't absolute, but vary according to how objects move relative to one another, so as to ensure that measurements of the speed of light always give the same result.

Following Einstein's publication of these astounding insights in 1905, a debate broke out over the resulting visual impact of these effects. The arguments centred on whether the predicted effects – such as length contraction – could be observed, given that both the effect itself and any attempt to observe it are affected by the speed of light. Definitive answers took decades to emerge, but they show that the shape, brightness and colour of objects are all affected. For example, an observer moving at near light-speed down a street would see the buildings on either side curl up to create the impression of flying down a tube. The view ahead, meanwhile, would appear brilliantly white, while to the rear everything would vanish into darkness. **RM**

Did you know?

The most accurate clock is the National Physical Laboratory's CsF2. It would take 138 million years for it to lose a second.

CLARA GILES SOUTHAMPTON

What happens when something is on the tip of your tongue?

THERE ARE TWO main theories for something being on the 'tip of your tongue'. One claims that the memory for the word is there but just not strong enough to be accessed. The other suggests that the person's memory provides genuine clues about the target word but cannot piece them together well enough. Emotional questions increase the chance of it happening and sometimes the answer just springs to mind some time later. **SB**

JAMES SMITH EDINBURGH

What proportion of swimming pool water is wee?

Make sure you shower *after* using the pool...

WHEN studying the effectiveness of swimming pool filtration systems, researchers talk in terms of 'body fluid analogue' or BFA. This is a mixture of sweat and urine, plus skin and faeces that represents the average concentration of pollutants from swimmers. Each person adds about 25ml of BFA to the water, 6.3 per cent of which is urea. The concentration of wee in a typical pool is about one part per million. Chlorine added to the water reacts with urea to remove it, but only about 1 per cent per hour is removed this way. **LV**

NEXT MONTH Over 30 more of your questions answered

For more answers to the most puzzling questions, see the Q&A archive at **www.sciencefocus/qanda**

PHOTO: THINKSTOCK X2, ALAMY

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HOW DO WE KNOW?

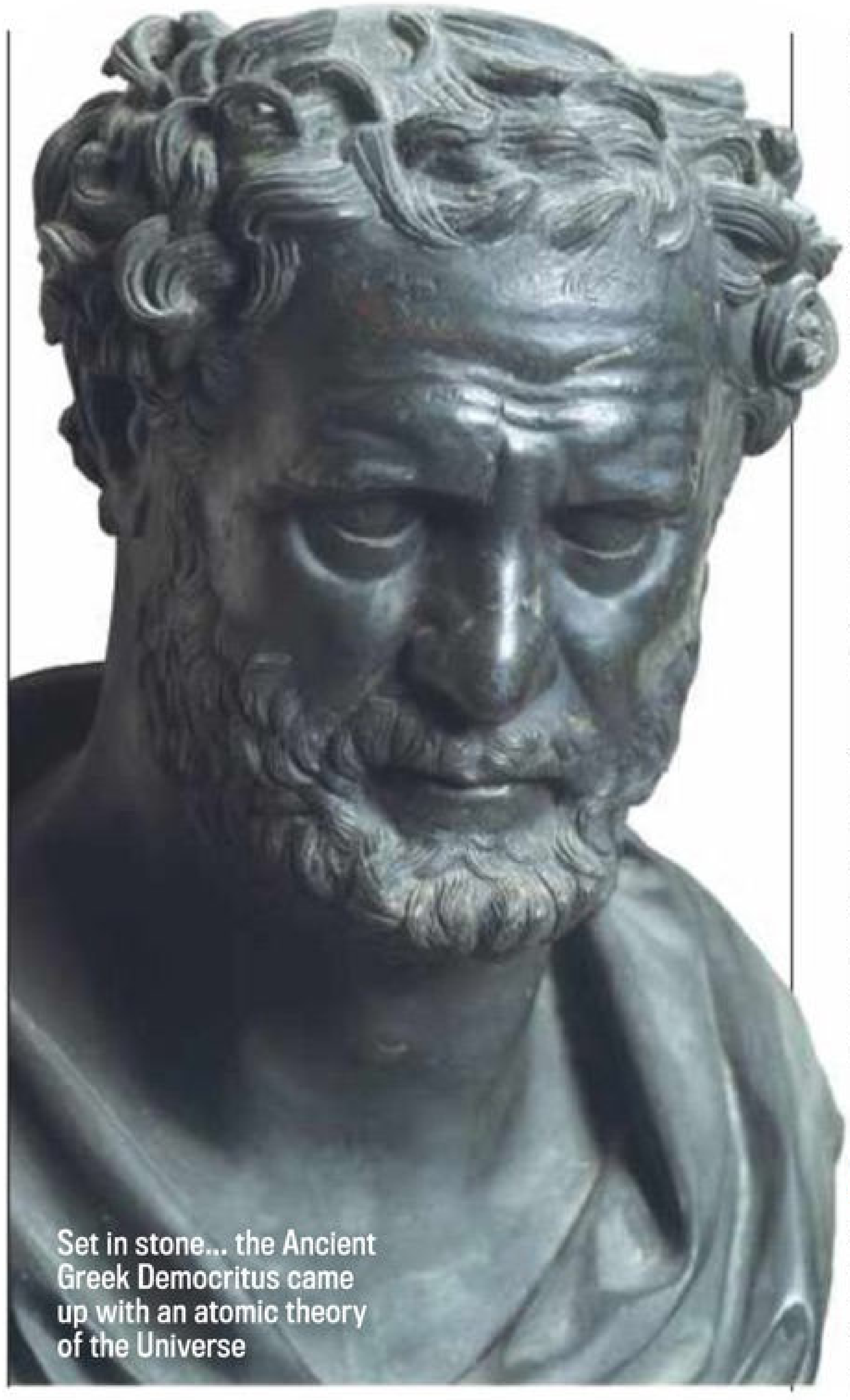
THE STRUCTURE OF THE ATOM

BY PROF FRANK CLOSE

Throughout history, we've endeavoured to find out what things are made of at the smallest scales of matter. Thanks to great scientists we now know the answer...

SOME 400 YEARS BC, in Ancient Greece, Democritus asserted that all material things are made from tiny basic objects – atoms – that cannot be divided into smaller pieces. "Nothing exists except atoms and empty space", ran their mantra, until Aristotle rejected atomic theory and the idea was ignored for nearly two millennia.

The Ancient Greeks also believed that everything was made from a few basic elements. The idea was right; the details were wrong. They thought that earth, wind and fire, along with water were the seeds of everything. Today we know that everything is made from chemical elements, such as hydrogen, carbon and oxygen. And these elements consist of atoms, which are too small to see by eye (hundreds of thousands could fit into the diameter of a human hair), but visible to special instruments. Whereas Democritus was right that an atom is the smallest piece of an element that is still identifiable as such, today we know of deeper layers to the cosmic onion. An atom is not the smallest thing: atoms are themselves divisible.



Set in stone... the Ancient Greek Democritus came up with an atomic theory of the Universe

Today, we know that if you cut into an atom of any element, you will find its common constituents: lightweight, negatively charged electrons in the outer regions and a positively charged nucleus, dense and massive, at the centre. The only difference between the atom of one chemical element and another is the amount of electric charge on its nucleus, and the number of electrons that can be ensnared by the rule: 'opposite charges attract'.

An atom of hydrogen, the lightest element, has a nucleus with one unit of charge, encircled by one electron. Helium, the next, has two, and the heaviest naturally occurring element, uranium, has 92. Obtaining this knowledge took scientists on a remarkable journey of discovery.

ATOMIC ALCHEMY

In the latter half of the 17th Century, Irishman Robert Boyle founded the atomic theory of matter. Boyle was an alchemist, carrying out

PHOTO: SCIENCE PHOTO LIBRARY, AKG IMAGES

> IN A NUTSHELL

From the first philosophical forays into the make-up of matter in Ancient Greece to the 20th Century's exploration of quantum theory, find out about the pioneering physicists and the ground-breaking experiments that have shown us the workings of the atom.

experiments that he hoped would change common elements, such as iron, into gold. Although he failed in this endeavour, he was the first to recognise that substances are compounds of basic elements, and to propose that these elements are composed of basic particles: atoms.

Boyle's ideas were descriptive only. Quantitative chemistry only came about in the late 18th Century when, in France, Antoine Lavoisier showed that the masses of individual elements stay the same – are 'conserved' – during chemical reactions. This led to the idea that basic elements were rearranging themselves in such processes. He also demonstrated that water is made from two elements: hydrogen and oxygen.

MASS EFFECT

In England in the early 19th Century, John Dalton suggested that all atoms in a given chemical element are exactly alike: the atoms of different elements being distinguished by their mass. He had discovered that the weights of the various elements involved in chemical reactions were always in simple numerical proportions. The simplest example involved the gases, hydrogen and oxygen, combining to make water.

Careful measurements showed that if all of the gases were to be used and none left over, the weight of the oxygen would need to be eight times as much as that of hydrogen. As two hydrogen atoms and one oxygen atom have combined to make a molecule of water – H_2O – this implies that one oxygen atom must weigh eight times as much as two atoms of hydrogen. So an atom of oxygen is 16 times heavier than one of hydrogen.

By studying lots of chemical reactions, and measuring the relative amounts of the elements involved, by the mid 19th Century the relative masses of their basic atoms had been determined. Relative to hydrogen, atoms of oxygen, carbon, calcium and iron weighed 16, 12, 40 and 56 times as much. This tantalising numerology was a hint that atoms of different elements may share some common ingredients, the atoms of the heavier elements having 'more' of the mystery material than the lighter ones. In other words: atoms are made of something even smaller.

With hindsight, by the middle of the 19th Century two discoveries held

> CAST OF CHARACTERS

The pioneers that have peeled back the layers of the atomic onion

John Dalton
(1766-1844)

An English chemist and founder of modern atomic theory. Born in Cumberland, he moved to Manchester where he taught mathematics and natural philosophy. He studied the behaviour of gases, and the atmosphere, but his most famous insights were with the atomic theory of chemistry, with which his name is associated.

Dmitri Mendeleev
(1834-1907)

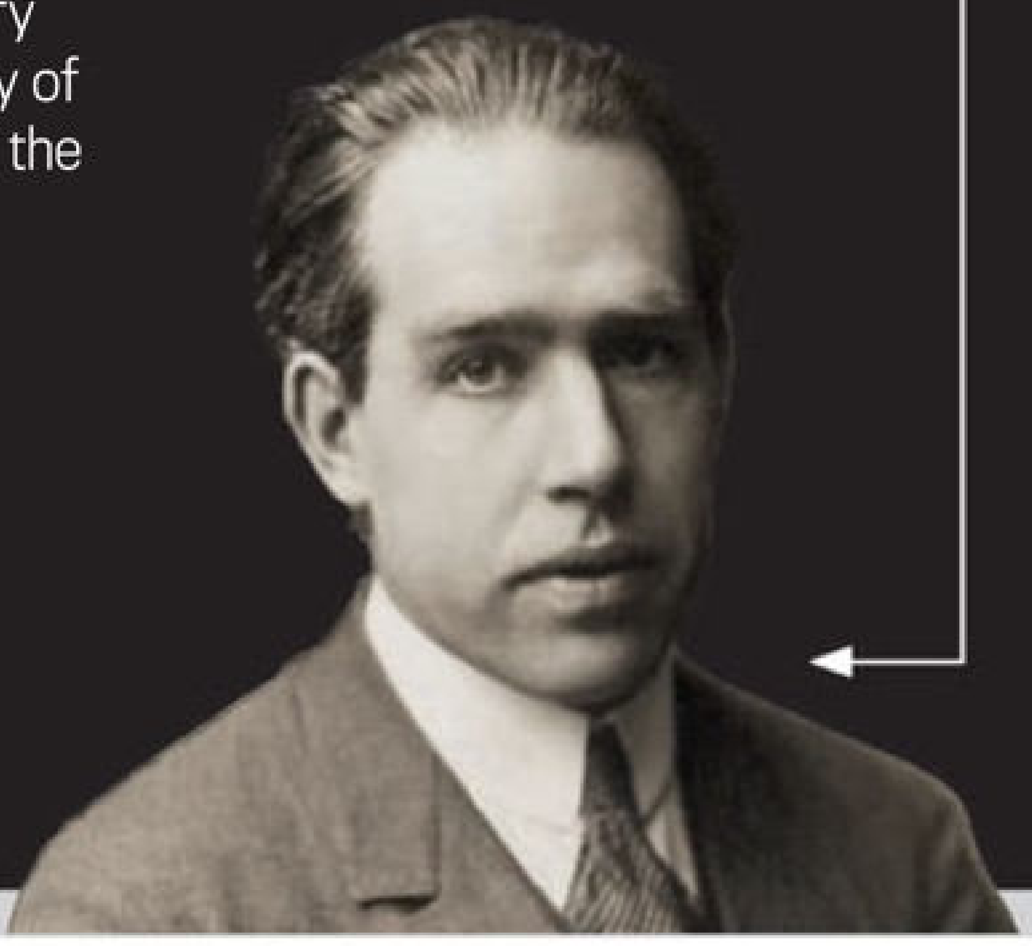
A Russian chemist, most famous for his Periodic Table Of The Elements, which he discovered while writing a textbook on chemistry in 1869. He was twice nominated for the Nobel Prize, in 1906 and 1907, but this was rejected after claims that his discovery was too old.

Joseph (JJ) Thomson
(1856-1940)

Born in Manchester, he joined Trinity College, Cambridge, in 1876. He spent the rest of his life there, becoming Master in 1918. His work on the properties of gases and atomic structure led to his discovery of the electron, in 1897, and a Nobel Prize in 1906.

Ernest Rutherford
(1871-1937)

The New Zealand-born British physicist is famous for discovering the atomic nucleus, identifying forms of radioactivity, and fathering the field of nuclear physics. Although he is best known for his discovery of the nuclear atom, his 1908 Nobel Prize was for chemistry and his discovery of transmutation of the elements.



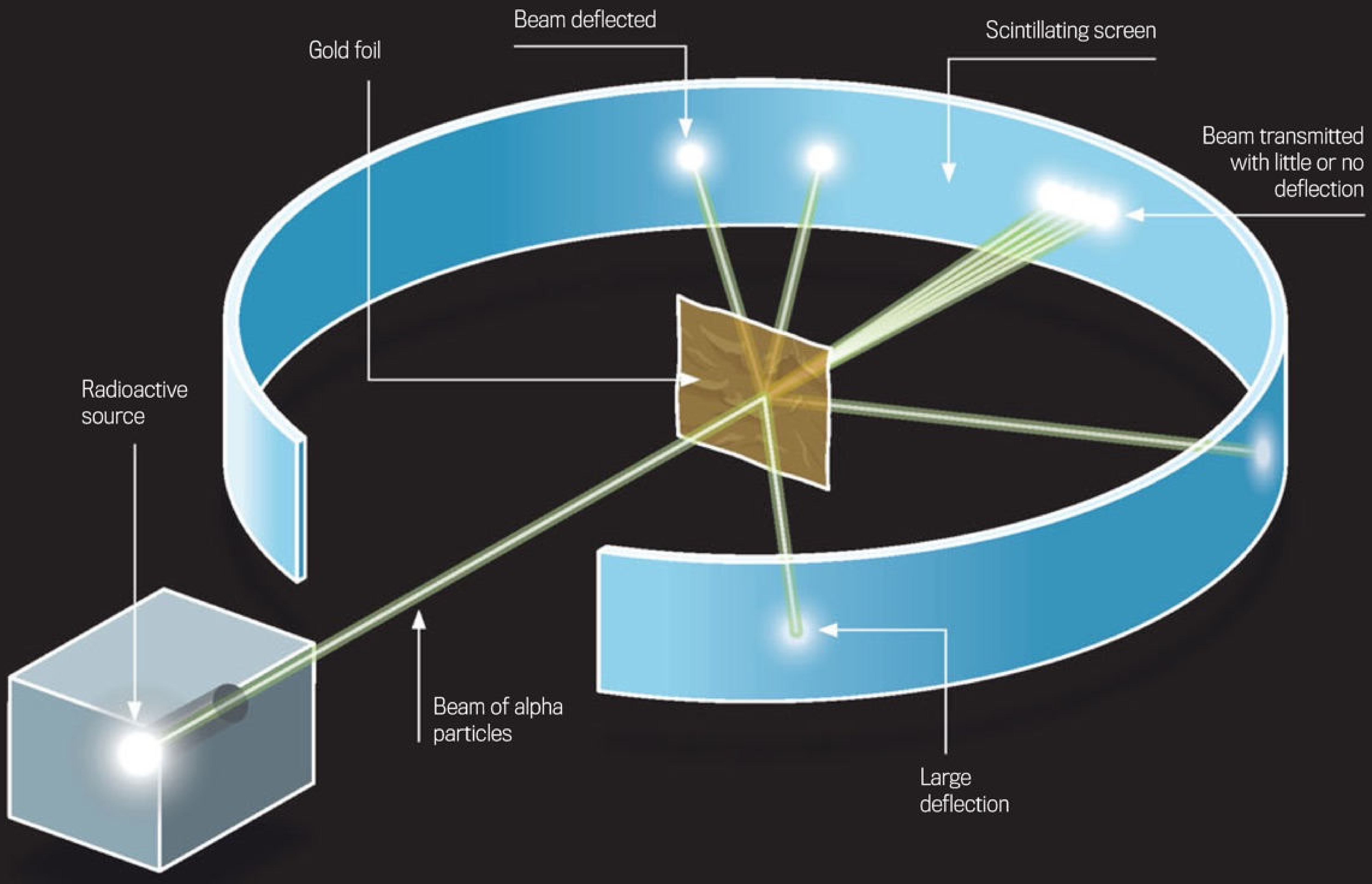
Niels Bohr
(1885-1962)

A Danish physicist who made major contributions to the foundations of quantum mechanics and to the theory of atomic structure. His planetary model was the forerunner of the modern picture of the atom. He won the Nobel Prize for physics in 1922.

PHOTO: SCIENCE AND SOCIETY PICTURE LIBRARY X2, ALAMY X2, CORBIS, RICHARDPALMERGRAPHICS.COM

> THE KEY EXPERIMENT

In his Manchester laboratory, the physicist Ernest Rutherford and his colleagues found a way to probe the heart of an atom



Early in the 20th Century, Ernest Rutherford noticed that thin sheets of mica could deflect alpha particles (see 'Need to know' p101), which were moving at 15,000km/s. This could only have happened if they felt electric and magnetic forces far greater than anything known. He mused that these forces might be present within atoms.

Rutherford suggested that his colleague, Ernest Marsden, look to see if any alpha particles were deflected through very large angles. Instead of mica, Marsden used gold leaf that was only a few hundred atoms thick, and a scintillating screen to detect the scattered alpha particles. To everyone's amazement he discovered that about one in 20,000 alphas were turned back in their tracks. Rutherford famously exclaimed: "It was as though you had fired a 15-inch shell at a piece of tissue paper and it had bounced back and hit you".

Rutherford realised that the positive charge in an atom is concentrated in a massive and exceedingly compact central 'nucleus', and that it was the repulsion of like charges that was deflecting the relatively lightweight alpha (the nucleus of a gold atom being some 50 times more massive than an alpha particle).

The size of the nucleus relative to an atom was famously compared to being like a "fly in a cathedral".

the clue that atoms have an inner structure. First was the phenomenon of atomic spectra. Here, when light emitted by hot elements was split into component colours, characteristic sets of lines showed up, like an atomic barcode unique to each element. While chemists used the phenomenon to identify elements, and even to discover new ones such as helium in the Sun, physicists found it too complicated to explain, and initially ignored it.

Second, Dmitri Mendeleev discovered that when he listed the atomic elements in order of their atomic weights, from the lightest, hydrogen, up to uranium, elements having similar chemical properties periodically reoccurred. His celebrated Periodic Table Of The Elements contained gaps, which led him to predict that further elements must exist to fill them. The discoveries of gallium, germanium and scandium, found in France, Germany and Scandinavia followed – you can easily tell which was found where!

Dalton had believed that atoms were indivisible spheres. But by the start of the 20th Century, clues were accumulating showing that atoms have an internal structure. In addition to spectra, and the periodic table, radioactivity showed that one element could transform spontaneously into another by emitting particles, a process known as transmutation. This raised two questions: what were the constituent parts of atoms and how were they arranged?

Answers came in 1897, when JJ Thomson found that electric current is carried by negatively charged particles: electrons. He was able to measure the ratio of an electron's charge

➔

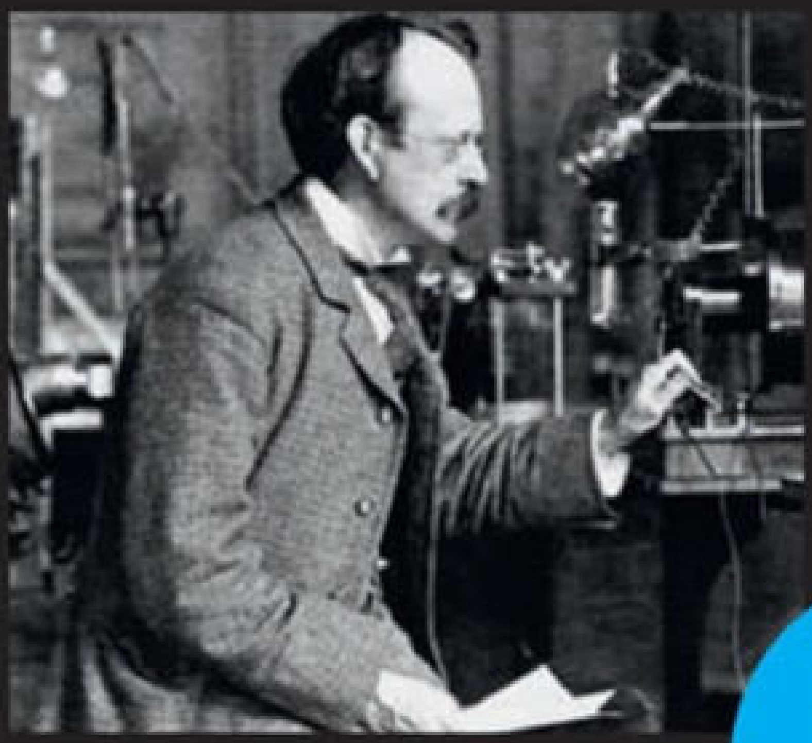
> TIMELINE

It has taken two centuries for some of the greatest physicists to get to the heart of the atomic world

1803

John Dalton proposes that all matter is made of indestructible atoms; that atoms of different elements are distinguished by their weights, and that chemical reactions occur when atoms are rearranged.

1897



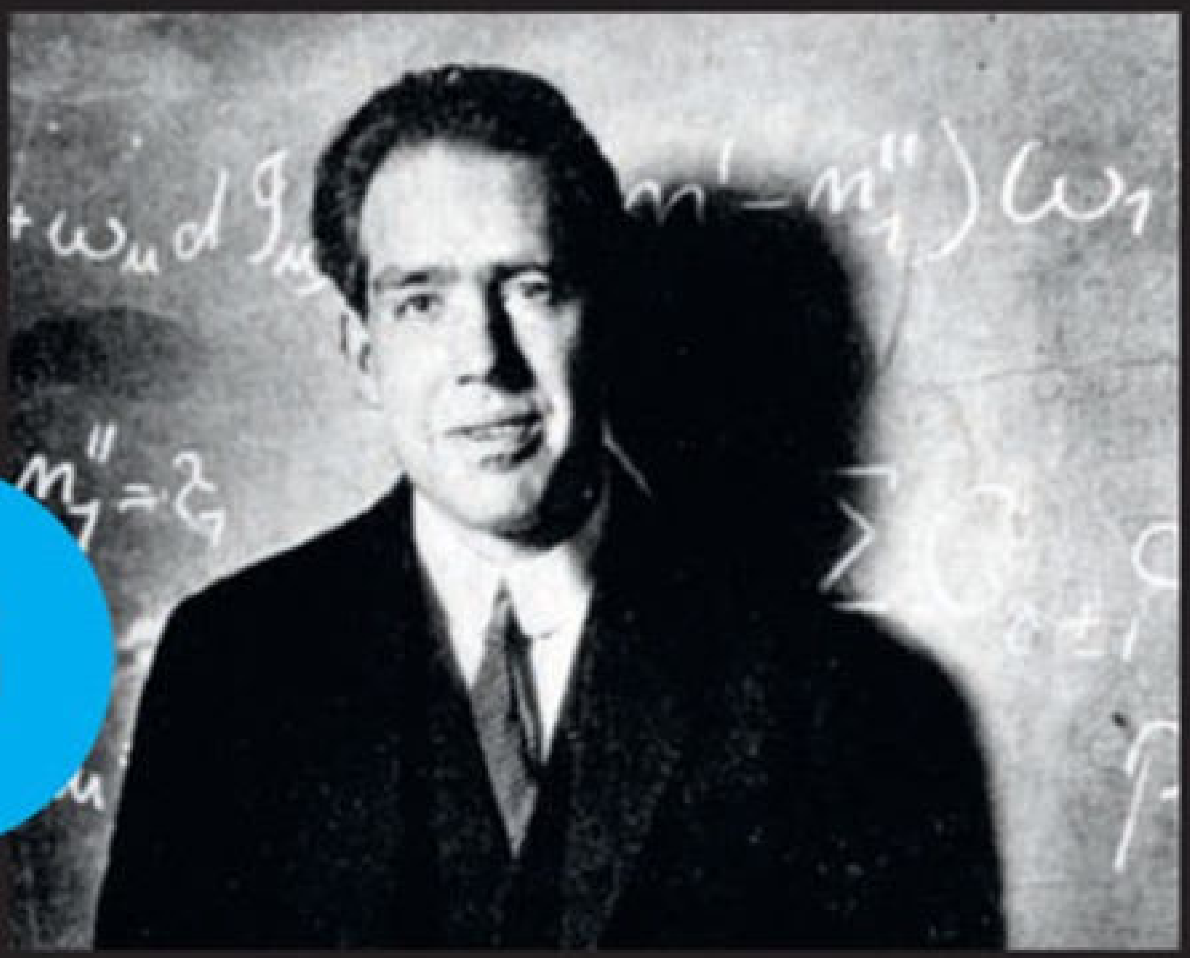
Joseph John ('JJ') Thomson (above) discovers the electron, and identifies it as a constituent of all atomic elements. It is negatively charged, which suggests that there must also exist positively charged constituents to neutralise the atom.

1911

Ernest Rutherford discovers the positively charged atomic nucleus following experiments by Hans Geiger and Ernest Marsden. He realises the nucleus is massive and compact, and that an atom is mostly empty space.

1913

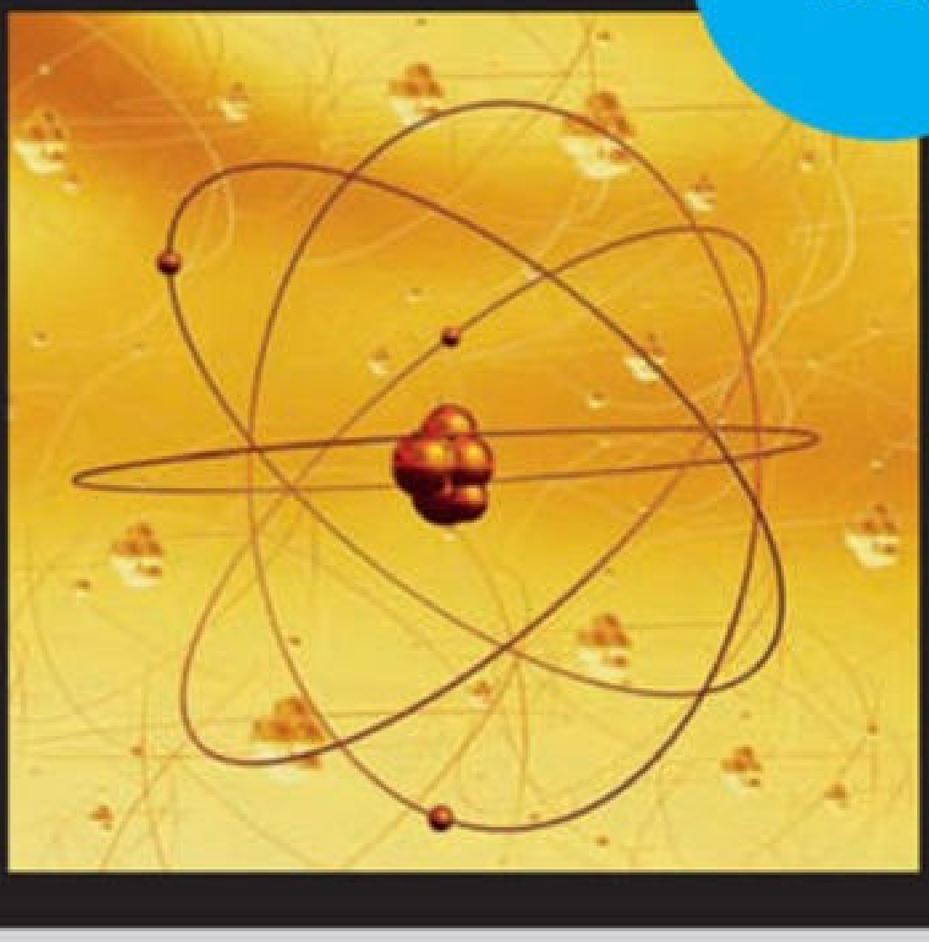
Niels Bohr (right) creates a conceptual picture of the atom like a miniature Solar System, where 'planetary' electrons orbit a central nuclear 'Sun'.



1925-28

Erwin Schrödinger produces a quantum theory of electron behaviour in the hydrogen atom in 1925. In 1928, Paul Dirac completes the theory, making it consistent with the theory of Special Relativity.

1932



Atomic nucleus established to consist of protons and neutrons. The proton and neutron are today known to be made of more fundamental seeds: quarks. The electron still appears to be indivisible.

PHOTO: SCIENCE AND SOCIETY PICTURE LIBRARY, CORBIS, SCIENCE PHOTO LIBRARY X2

to its mass, and found that this was very large and common to all elements that he used. He deduced that electrons are a feature of all elements.

American Robert Millikan measured the electric charge of the electron, which, combined with Thomson's result for the ratio of charge to mass, showed that this ratio is large because the mass of an electron is very tiny, only about 1/2,000th that of a hydrogen atom, the lightest known. This led to two inferences: as electrons are so light, there must be other more massive particles in there too. And as atoms have no overall electric charge, the massive particles must be positively charged in order to neutralise the electrons' negativity.

SCIENCE IS GOLDEN

When Ernest Rutherford and his assistants Hans Geiger and Ernest Marsden bombarded atoms of gold with alpha particles – massive, positively charged particles emitted in radioactivity – they found that most of them passed through, but occasionally one would recoil violently (see 'Key experiment', p99). In 1911, Rutherford deduced that the gold atom must be mostly empty space, but with a dense massive central region, capable of deflecting the alpha particles. He called this the nucleus.

The nucleus of a hydrogen atom is the simplest of all, consisting of a single positively charged 'proton'. The nuclei of heavier elements contain several protons – helium has two, uranium 92 – whose combined positive charge ensnares negatively charged electrons to form the atom. It is the larger number of protons in atoms of elements such as uranium that helps give them a larger atomic weight than hydrogen.

However, protons alone don't explain the exact values of the atomic weights: all elements other than hydrogen contain neutrons, which have no electric charge, in addition to protons. Neutrons add to the mass of the atom but leave its chemical properties unchanged. A given elemental atom can occur with different numbers of neutrons. Such alternatives are known as isotopes. Even hydrogen has isotopes: 'heavy water' is the result of a hydrogen atom having a proton and a neutron.

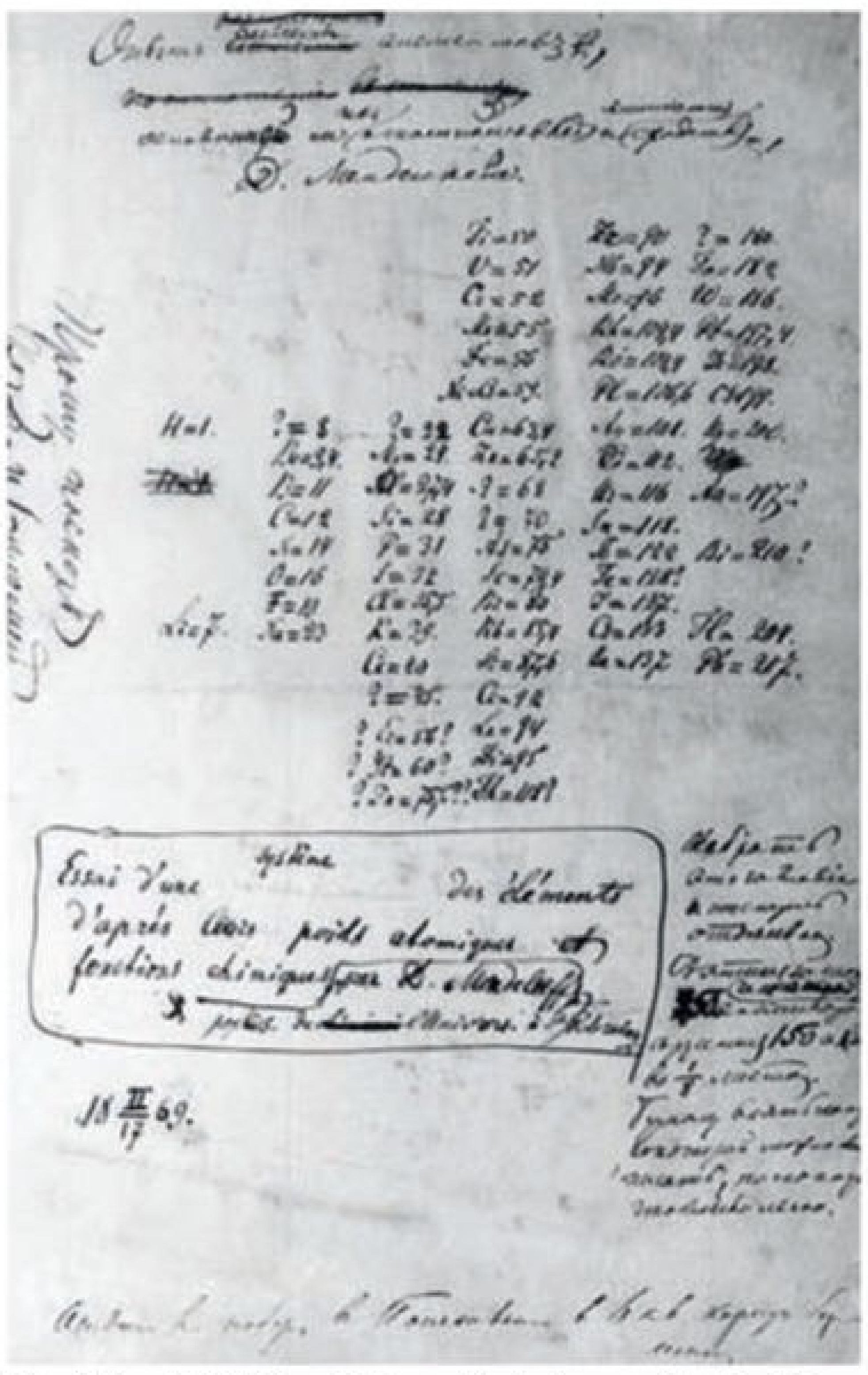
When Rutherford's discovery of the positively charged atomic nucleus and Thomson's discovery of the lightweight, negatively charged electron were married with the rule that opposite electrical charges attract, a seductively simple picture emerged of the atom as a miniature Solar System. In this naive analogy, the nucleus plays the role of the Sun, and electrons are like the remote planets.

However, had electrons in atoms encircled the central nucleus like planets orbiting the Sun, obeying Newton's laws of motion, they would have spiraled into the nucleus within a mere fraction of a second. An atom, once formed, would self-destruct in a flash of light almost immediately; matter would not exist.

QUANTUM LEAP

Something was missing. The final ingredient was the discovery of quantum theory: very small things, such as atoms, follow different laws from those of Newton, which explain the behaviour of objects that are large enough to see. Instead of an electron being able to go anywhere in an atom, it is limited, like someone on a ladder who can step only on individual rungs. Electrons in atoms follow a fundamental regularity, each rung corresponding to a state where the electron has a unique amount of energy.

Danish physicist Niels Bohr articulated the idea in the summer of 1912. When an electron drops from a rung with high energy to one that is lower down, the excess energy is carried away by a photon of light. Conversely, if an atom is hit by a photon whose energy matches the gap between two rungs, the atom absorbs that photon, lifting the electron up the ladder.



Mendeleev's 1869 periodic table had gaps that led him to believe that some elements remained undiscovered

This absorption effect became obvious when sunlight was examined. Like all stars, the Sun emits electromagnetic radiation across the entire spectrum. It also has a lot of gas in its outer atmosphere, containing a smorgasbord of elements. In sunlight, the photons with energies that happen to match the gaps between rungs in the atomic ladders are absorbed by the atoms of these elements and never reach Earth. By viewing starlight through a diffraction grating (a piece of glass scratched with close-packed grooves), you split light into its component colours. These 'missing' photons show up as dark lines.

Quantum theory goes one step further to explaining where electrons can be around a nucleus. Any particle can take on a wave-like character. What is familiar for electromagnetic waves occurs for electrons too. You can imagine the waves for electrons in atoms as if they were wobbles on a length of rope. When coiled like a lasso, the number of wavelengths in the circuit has to fit perfectly into its circumference. Imagine this circle like a clock face. If the wave peaks at 12 o'clock, with a dip at 6 o'clock, the next peak will occur perfectly at 12: the wave 'fits' into the circle. However, a peak at 12 followed by a dip at 5 o'clock would have its next peak at 10 and be out of time with the beat of the wave: the wave will not fit. Therefore, electrons circulating in atoms can only go on paths where their waves fit perfectly on the lasso. A single wave corresponds to the lowest rung of the energy ladder; two waves puts the electron on the second rung and so on.

The energies of the various waves are unique to atoms of a given element. The spectral lines that result when electrons jump from one rung to another are therefore like a barcode, identifying the elements present in the Sun and other stars. It also explains the periodic regularity in chemical behaviour noticed by Mendeleev in the 19th Century. So although we can't directly 'see' the electron waves within atoms, this hypothesis describes a host of historical phenomena and has led to a wealth of technological applications. We can therefore claim to 'know' a great deal about the inner structure of the atom, even though it is a world beyond Lilliput. ■

FRANK CLOSE is a Professor of Physics at the University of Oxford and the author of *The Infinity Puzzle* (OUP, £16.99)

> NEED TO KNOW

Five key scientific terms that will help you understand atoms

1 Alpha particle

A positively charged object emitted in a form of radioactivity. Originally thought to be a simple particle, hence the name, today we know that it consists of two protons and two neutrons tightly bound together. Some heavy nuclei are unstable and spontaneously emit these clumps in what is known as alpha radioactivity.

2 Scintillator

When some materials are struck by an incoming particle, the energy that is absorbed is then emitted as light. A screen coated with zinc sulphide emits faint flashes, visible in a darkened room, when hit by alpha particles. Early in the 20th Century, Rutherford detected alpha particles this way, revealing the atomic nucleus.

3 Element

All substances are made from combinations of chemical elements, which consist of atoms. Examples of elements are hydrogen, carbon and oxygen.

4 Photon

In quantum theory, light waves act as if composed of a series of individual particles, called photons. A photon is therefore a particle of light, with no mass.

5 Radioactivity

Atoms of one atomic element may transform spontaneously into another by emitting particles, a process known as transmutation.

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People who eat nutritionally inadequate meals may especially benefit from vitamin and mineral supplementation.
† Professor Beckett is not cited in the capacity of a health professional, but as a product inventor and former Chairman of Vitabiotics.

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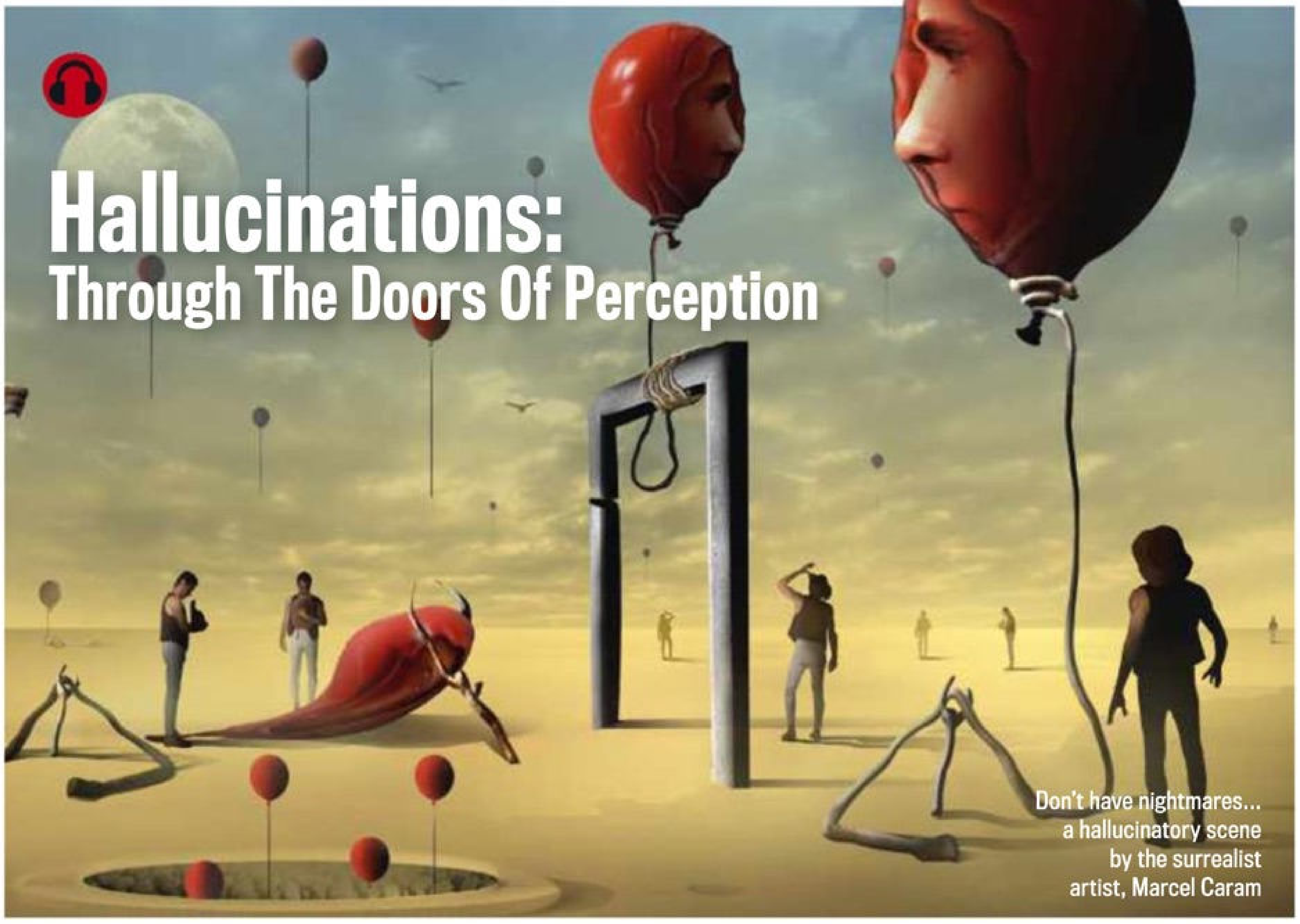
PICK OF THE MONTH



Hallucinations:

Through The Doors Of Perception

Don't have nightmares... a hallucinatory scene by the surrealist artist, Marcel Caram

➔ SAVE FOR A brief period in the 1960s when scientists became particularly interested in the drug LSD, hallucinations have been an understudied phenomenon in psychology. But that's beginning to change. Since 2010, nearly 500 new research papers have been published on the topic. Their aim: to understand which part of the brain conjures up these apparitions and what this tells us about the mechanics of the mind.

In the Radio 4 programme *Hallucinations: Through The Doors Of Perception*, presenter Geoff Watts speaks to scientists trying to investigate them. Take Dr Dominic Ffytche, for example, at the Institute of Psychiatry at King's College London. He uses flashing lights to induce hallucinations in volunteers while scanning their brains to uncover which areas are working to produce visions. Or there's Dr Kelly Diederen from the University of Utrecht in the Netherlands, who investigates patterns of neural activity in schizophrenics. A team in Switzerland, meanwhile, that thinks hallucinations could be the result of 'faulty circuitry' following some kind of physical or psychological trauma, akin to the experiences of 'phantom limb' pain in amputees.

Rather than just relying on scientists to tell us about hallucinations, the programme draws from first-hand experiences to demonstrate that seeing isn't always believing. Listen out for one individual who suffers from Charles Bonnet Syndrome (CBS), a condition that causes sufferers to see Lilliputian versions of their friends and family. It affects around 10 per cent of people suffering from vision loss. The programme discusses not just the science, but changing attitudes too.

BBC RADIO 4 92–95FM 198LW

***Hallucinations* airs in the week commencing 15 October on Radio 4**

PHOTO: GETTY

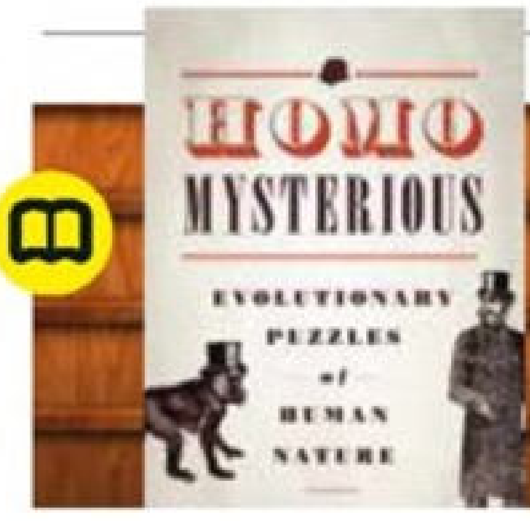
DON'T MISS!

Science Uncovered

Spend a night at the Natural History Museum and meet its team of expert scientists. **p104**

Human Nature

What makes us do the things we do? Evolutionary biologist Dan Riskin explores our peculiar behaviour on *Discovery*. **p106**



Homo Mysterious

Why do we behave the way we do? David Barash's new book offers some fascinating insights. **p110**

VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

20 SEPTEMBER

Darwin Themed Tour

Wellcome Collection, London, 2.30pm-3pm, free, www.wellcomecollection.org

CHARLES DARWIN'S THEORY of natural selection shook the Victorian world, but cemented him in the annals of science. How is the influence of Darwin's work felt today? This short guided tour of the Wellcome Collection looks at the great naturalist's life and work, and examines the influence and impact of his theories and papers. No need to book, just meet your guide beside the information desk.

21-28 SEPT

Gravity Fields Festival

Gravity Fields Festival, Lincolnshire, check gravityfields.co.uk for details of individual events and prices

WE'RE GUESSING WHEN Isaac Newton was developing his theory of gravity, his real wish was that he'd become famous enough to have his own festival. Okay, maybe not, but Lincolnshire is celebrating its most famous scientific son this month anyway, with a full week of science talks, exhibitions and explosive demonstrations linked to the pivotal physicist – all in the hope of inspiring the next little Newton.

28 SEPTEMBER

Test Tube To YouTube

Royal Institution, London, 8pm-9.15pm, £15/£10, www.rigb.org

FROM *TOMORROW'S WORLD* to *Bang Goes The Theory*, science continues to reinvent itself on the small screen. At this talk, scientist Martyn Poliakoff and colleagues take a look at science on TV, and at how it's also hijacked YouTube with channels such as periodicvideos.com – a series of over 400 chemistry videos that have attracted more than 23 million views. Take some tips if you fancy becoming the next Brian Cox.

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)

Spend a night at the museum. Relax, it's guaranteed 100 per cent Ben Stiller-free!

28 SEPTEMBER

Science Uncovered

EDITOR'S CHOICE

Natural History Museum, London, 4pm-11pm, free, www.nhm.ac.uk/scienceuncovered

WE'VE LONG DREAMED of having unrestricted access to the Natural History Museum after hours, but for some reason the curators don't seem to want to lend us the keys. Until then, this event will have to do. The museum will be throwing its doors open for a night, so you can meet some of the 300-strong team of scientists that work behind the scenes at the museum every day. Collectively, they research everything from the origin of meteorites to potato diversity, and forensic entomology to the evolution of dwarf elephants.

With drink in hand, you can quiz the researchers manning various Science Stations dotted around the galleries, and get hands-on with specimens that aren't normally on display to the public – the museum houses nearly seven million samples in total. You can also try your hand at extracting DNA, or climb into the actual tent used by scientists on field trips in Antarctica.

PHOTO: NATURAL HISTORY MUSEUM, UNIVERSITY OF BRISTOL, SCIENCE AND SOCIETY, GETTY, THINKSTOCK X2

10 OCTOBER

Smart Signing

Waterstones, Aberdeen, 7pm, free, j.mp/CafeSigning

THE WORD LENS app translates printed words from one language to another – useful when travelling abroad to avoid eating something dodgy or walking off a cliff. Imagine being able to do this with someone using sign language, their words simply scrolling across the screen. At this Café Scientifique event, Dr Ernesto Compatangelo explains how this dream could soon become a reality.

11 OCTOBER

Food Detectives

Pfizer Lecture Theatre, University of Cambridge, 7pm-8pm, free, talks.cam.ac.uk

AS A CHEMIST, Dr Ellen Norman is called in to investigate when cooking goes bad – when big food production companies need to discover why batches of ingredients get contaminated or don't combine in the right way. In this talk, she reveals the processes employed to solve the mysteries – from mass spectrometry to old-fashioned wet chemistry techniques. We recommend having your dinner *before* you turn up.

16-21 OCTOBER

Sidmouth Science Festival

Sidmouth, see www.sidmouthsciencefestival.org for details of events and prices

CAN A SEAGULL'S wings influence the weather? Dr Ken Mylne from the Met Office will demonstrate that the answer isn't as simple as you'd expect at this new science festival, created in conjunction with the people behind Café Scientifique. Quantum theory and the science of brewing are also on the menu, plus guitar physicist Dr Mark Lewney plays some licks on the fretboard.

22 OCTOBER

Curiosity: How Science Became Interested In Everything

Life Science Centre, Newcastle, 6pm-7pm, £2, http://philip-ball-curiosity.eventbrite.com

WE NO LONGER just share niceties around the dinner table... it's all about dropping the latest 'wow' fact into conversation, and it helps if it's backed up by science. Join Philip Ball, author and a former editor at the journal *Nature*, as he reveals how being inquisitive makes the world go round.

SPEAKER OF THE MONTH

23 OCTOBER

Prof Peter Barham

Royal Geographical Society, London, 7pm, £25, www.intelligencesquared.com/events

Who is he?
As a professor of physics at the University of Bristol, Prof Barham studies how molecules organise themselves into larger structures. In recent years, he has taken this and applied it to the field of cooking, to create unusual textures and flavours. Barham's work has helped Heston Blumenthal perfect his recipes, and he's also now editor of *Flavour*, an academic journal dedicated to molecular gastronomy.

What's he talking about?
Good food: Barham hopes to explain the core physical processes that underlie great cooking. He'll be joined by *Sunday Times* food critic AA Gill and Dr Mark Post, a physiologist who's been trying to grow artificial meat in the lab.

UNTIL 28 OCT

Ariel 1

Science Museum, London, free, www.sciencemuseum.org.uk

LAST CHANCE TO SEE

Ariel 1 paved the way for today's thriving UK satellite industry

DON'T MISS THIS opportunity to see the world's first international satellite. NASA launched Ariel 1 in 1962, but it carried experiments devised and operated by British universities. Ariel's launch made the UK the third country to operate a satellite, after the USA and the Soviet Union, and kick-started our now thriving satellite industry. Of course, the original disintegrated on re-entry to Earth's atmosphere, but this exhibition has a life-sized model of the satellite as well as models of many of its successors.

WATCH

TV, DVD & BLU-RAY

WITH TIMANDRA HARKNESS

FROM 23 SEPT

Body Invaders

Discovery HD, starts 23 September, 10pm

YOU CAN PROBABLY imagine accidentally swallowing an engagement ring. But an aeroplane part? This series explores some of the oddest foreign objects ever to find their way inside a human body, and the unlikely stories of how they got there. You'll be glad to hear that medical explanations and victim accounts are supplemented by CGI, so the Scottish girl impaled on railings, and the gardener who sticks his shears in his own eye, can be seen in their full glory. Or do we mean gory?

FROM 25 SEPT

Mighty Planes

Quest, starts 25 September, 9pm

IT'S HARD TO believe that the aeroplane is little over a century old, as we routinely board them without a second thought. But the machines in this six-part series reveal just how far the engineering has come since the Wright brothers' first attempt. Discover the technology behind the world's first superjumbo passenger plane, and the world's only flying hospital. And to start: the world's biggest seaplane, scooping up water to fight forest fires in Mexico. Orville and Wilbur wouldn't believe their eyes.

FROM 1 OCT

How Britain Was Built

Military History, starts 1 October, 7pm

LANDMARK STRUCTURES LIKE bridges, buildings and transport routes are just part of our landscape today, but when they were constructed they changed Londoners' lives forever. Historic technology lover Adam Hart-Davis presents this eight-part series, telling the stories of key edifices such as pubs, tunnels and tall buildings, and what they reveal about the city's past. Discover what links beer and the Industrial Revolution, or St Bride's Church and wedding cakes. And have some sunglasses handy for the presenter's garish outfit.

TIMANDRA HARKNESS is a BBC Radio 4 presenter and stand-up comic. Her latest show is 'Humans Vs Nature: Engineering FTW'.

Evolutionary biologist Dan Riskin wants to know why people behave in unusual ways

FROM 1 OCT

Human Nature

EDITOR'S CHOICE

Discovery Science, starts 1 October, 10pm

➜ WHAT MAKES PEOPLE do the things they do? That's the question that evolutionary biologist Dan Riskin will be addressing in this new four-part series.

Often, our behaviour is dismissed as "just human nature", whether it's male infidelity, our inbuilt urge to compete or a fear of spiders. But does the term have any scientific basis? Debate rages as to the conflicting roles of nature and nurture in shaping the people we become. Riskin believes much of our behaviour can, indeed, be explained by the lives our ancestors were forced to lead, and so in this series he travels the world looking for evidence. How did we develop our capacity for memory, and do we have unexplored potential? What role does fear have in our lives now, and what role did it have millennia ago?

Along the way Riskin talks to a number of people whose behaviour has been well outside the norms, such as serial killer Elmer Wayne Henley Jr – convicted in 1974, aged 18, for his part in helping an older man abduct, rape, torture and murder at least 28 teenaged boys. Is Henley just evil, asks Riskin? Was he a product of his environment (he was raised by a wife-beating alcoholic father)? Or is there something in his brain, something in his genes – a throwback to mankind's earliest days on the savannah – that inclined him to such depraved actions?

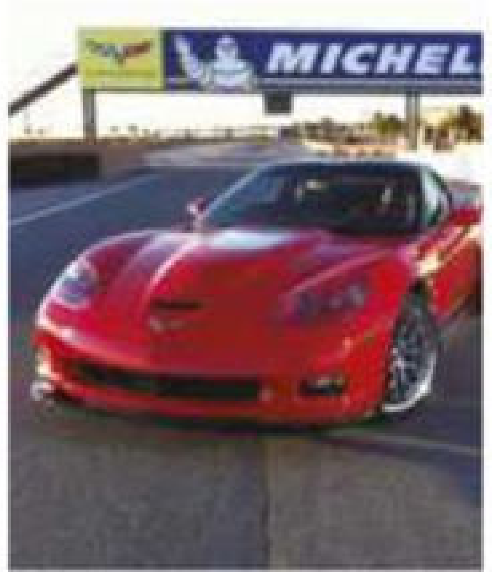
The subject of death will also rear its head in another episode, in which Riskin gets to grips with the subject of human mortality. Is our lifespan coded into our genes, as some believe, or – as others believe – could advances in medical science see humans living much, much longer… possibly forever? To find out, Riskin takes part in a series of limits-testing experiments and explores the latest research in the field of cryogenics.

PHOTO: DISCOVERY NETWORK X3, NATIONAL GEOGRAPHIC CHANNEL X2, IWP KOMMUNIKACIO

FROM 1 OCT

Supercars

National Geographic, starts 1 October, 7pm



However sensible your family runaround, you have to admire the outrageous engineering that goes into the world's most powerful cars. The first programme in this eight-part series follows the birth of a new Lamborghini, from initial concept to the first cars leaving the factory. With a top speed of 350km/h the Aventador has an innovative carbon-fibre monocoque design. Other episodes look at classics like the Ford Mustang, Corvette ZR1 and Porsche 911.

7 OCTOBER

History Of The World In Two Hours

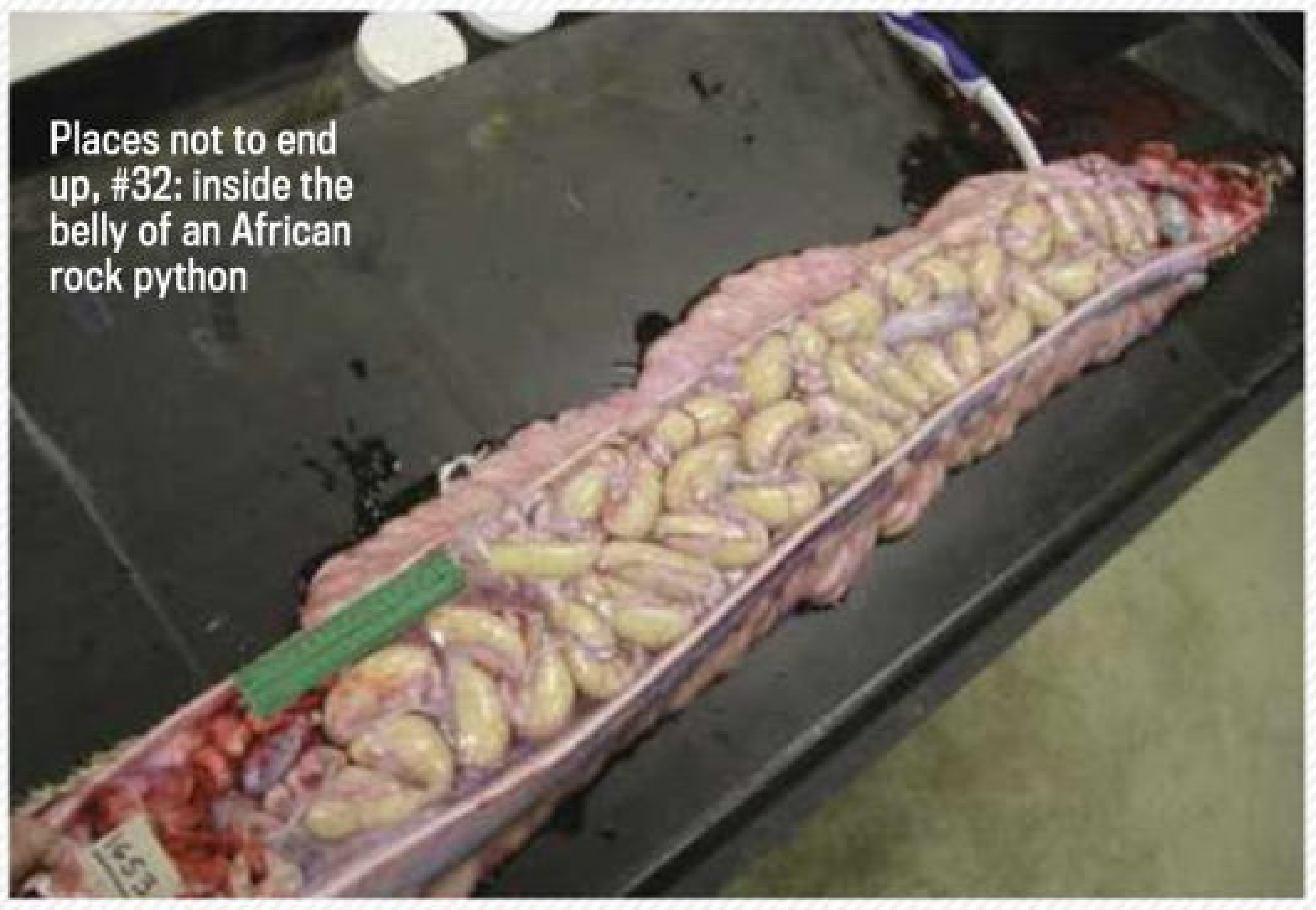
History, 7 October, 9pm

This one-off special packs 14 billion years of our Universe's history into 120 minutes. With under 10 minutes per billion years, don't expect a detailed discussion of the Tudors or the Anti-Corn Law League. But as well as some top CGI spectacles, we are promised some pauses to take a closer look at key turning points and at how the distant past still echoes in our lives.

23 SEPTEMBER

Man-Eating Super Snake

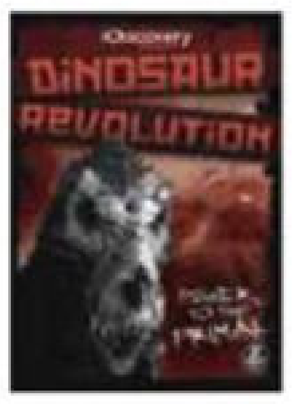
Animal Planet, 23 September, 9pm



Places not to end up, #32: inside the belly of an African rock python

SOUTH FLORIDA IS a dangerous place. As if the native alligators weren't enough, west of Miami there are African rock pythons living wild. Big enough to crush and eat a person, they're one of the most aggressive snakes in the world, as the biologists in this one-off programme explain. But what really worries the experts is the prospect that they could reach the Everglades and interbreed with another species, the Burmese python. Hybrid man-eating supersnakes on the rampage in Florida, anyone?

DVD & BLU-RAY



Dinosaur Revolution

DVD and Blu-Ray, Discovery Channel, £14.99

The 'revolution' is in our knowledge: it turns out dinosaurs resembled birds more than lizards, with colourful feathers and complex social systems. With nearly three hours of CGI, pterosaurs take flight and the fearsome *T. Rex*... builds a nest with its mate? We're in for a few surprises.

Prophets Of Science Fiction

DVD, Discovery Channel, £29.99

From *Frankenstein* to *Star Wars*, writers have imagined the future, and in some cases (such as Asimov and Clarke) helped shape it. Each episode of this series looks at a different science fiction author, from HG Wells to Philip K Dick, and how their ideas took form in the real world.

Sci Fi Science

DVD, Discovery Channel, £24.99

Physicist Dr Michio Kaku examines the science facts behind science fiction faves. So, for instance, we learn about lightning, lasers and nanotech as we see how close to a light saber we can get with today's technology. Star ships, robots and force fields are among Kaku's other challenges.

9 OCTOBER

Earth From Space

National Geographic, 9 October, 8pm

We now have so many satellites looking down at us that somebody had the bright idea of making a two-hour documentary about Earth from their point of view. This project reunites some of the team behind *Stephen Hawking's Universe*. Combining raw satellite data and CGI into sumptuous HD footage, the show makes visible the complex processes of physics, chemistry and biology that make our home hospitable to life. You might just have a bit more sympathy for hapless weather forecasters.

SEPTEMBER

Generation Earth

BBC One, September

Humans have changed the landscape for as long as farmers have ploughed and irrigated. But since the Industrial Revolution our capacity to transform our world has rocketed. For example, in the last century we've gone from the first flimsy aeroplanes to space travel. Dallas Campbell explores how technology has changed human life in 100 years, from the skyscrapers and sewers that enable us to live in cities, to the food and fuel that keep us going.

LISTEN

BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

FROM 1 OCT

The Digital Human

Radio 4, starts 1 October

Aleks Krotoski returns with the series that gets under the fancy case of our hi-tech age, unlocks the SIM of jargon and hacks the motherboard of what it all means, using themes such as religion, memory and privacy to examine how the digital era is transforming the way we live and relate to each other. Prepare to have your horizons widescreened.

FROM 1 OCT

The Museum Of Curiosity

Radio 4, starts 1 October

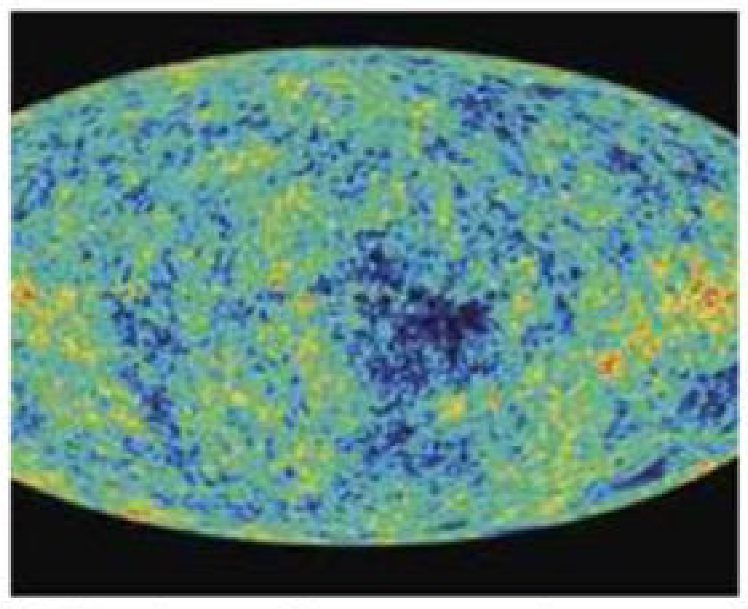
The show in which guests donate new 'exhibits' and talk about why they should be included. Previous 'donations' include the Holmdel Horn Antenna (key to the discovery of cosmic microwave background radiation), an Icelandic volcano and a giant snowflake that's symmetrical in 196,883 dimensions.

FROM 10 OCT

The Moral Maze

Radio 4, starts 10 October

Each week a panel gets to grips with a topical moral dilemma, hearing from witnesses on all sides of the issue before trying to reach an ethically justifiable position. As the chosen subjects reflect the news, we don't know what will be in the new series, but past topics have included organ donation, the impact of social media and how much access drug companies should have to NHS patient data.



CMB radiation, first measured using the Holmdel Horn Antenna in the 1960s

FROM 24 OCT

Undone

Radio 4 Extra, starts 24 October, 6.30pm

If you like surreal, satirical science fiction you're in luck, as Alex Tregear returns as Edna Turner in a new series of Ben Moor's fantastical parallel universe comedy, set in a city which isn't quite London. Then again, London has experienced some odd events recently – there've been reports of strangers talking to each other on public transport and Britons winning at sport – so perhaps the strange city of *Undone* is the real one, and we're the ones living in a bizarre, imaginary world…

FROM 30 OCT

All In The Mind

Radio 4, starts 30 October

The return of the series that covers psychiatry, psychology and mental illness, combining topical stories and current scientific research. Previous episodes have covered topics as diverse as a vaccine against depression, baby comedy and the psychology of internet dating. We're almost certain the next series will investigate psychic abilities to predict the future…

TOUCH

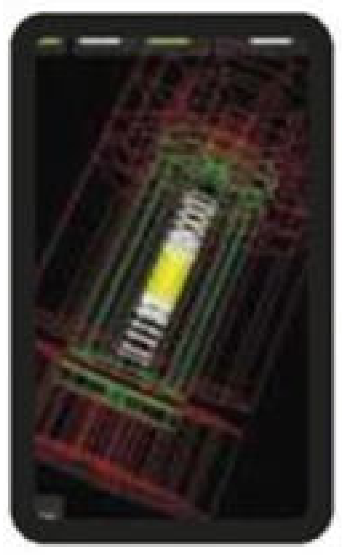
SMARTPHONE & TABLET APPS

WITH CHRISTOPHER PHIN

NHM Evolution

iOS (iPad), Authored Apps Ltd, £9.99

Wander round the Natural History Museum without braving London's rain and trains with this app, which tells the story of evolution through the museum's collection of fossils. Accessible captions on everything from trilobites to *T. rex* offer a solid foundation of knowledge, although the scarcity of videos or 360° images means this app feels more like visiting the museum's website than seeing the exhibits. Take your iPad along on an actual trip, however, and this virtual tour would enhance the experience.



LHSee

Android 2.2 or later, Christopher Boddy, free

If you can't quite rustle up six billion quid to build your own Large Hadron Collider, explore CERN's with this free app. The old-fashioned wire-frame models and basic colours mean it's not pretty, but you can see the trails and patterns of particles in experiments as soon as they're recorded at the LHC, and can zoom in on detectors and rotate the results in 3D. Created by a researcher at Oxford University, it's probably not for those with a passing interest in particle physics – the multiple-choice quiz, especially, is baffling.

IBM THINK

iOS (iPad), IBM Corp, free

Although clearly a PR exercise for IBM, this app – which tells the story of how science has developed over time – is nevertheless a pleasant way to spend an afternoon. Through tappable illustrations you learn how phenomena such as earthquakes and even nanometres are observed and measured, with clever juxtapositions of historical and contemporary maps to show how our understanding of the world has changed. You could finish working your way through the entire app over a couple of cups of tea, but what's here is well presented and interesting.

CHRISTOPHER PHIN is the editor of *TAP!* magazine

PLAY

CONSOLE & COMPUTER GAMES

WITH NEON KELLY

XCOM: Enemy Unknown

PC, Xbox 360, PS3; £39.99

GOOD NEWS: A terrifying alien civilisation is invading Earth and, as the leader of a poorly funded international task force, you're the only one who can stop them. *XCOM* reinvents one of the best strategy games of all time, retaining the original's nerve-shredding tension and adding a few tricks of its own. Between missions you'll need to research new technology and study the alien menace. Just don't get too attached to your loyal troops: disastrous surprises are an *XCOM* tradition.

Dishonored

PC, Xbox 360, PS3; £39.99

HOW DO YOU like to approach a task? Do you enjoy crawling in shadows, stopping time so that you can slip past the guards? Perhaps you prefer teleportation, or summoning a wave of rats to act as a vile distraction? These are your tools as you explore the dystopian city of Dunwall – a metropolis that blends steampunk gadgetry with the style of 19th Century London. As the outcast Corvo, bodyguard to a slain empress, you must find the traitors who framed you – and then administer justice.

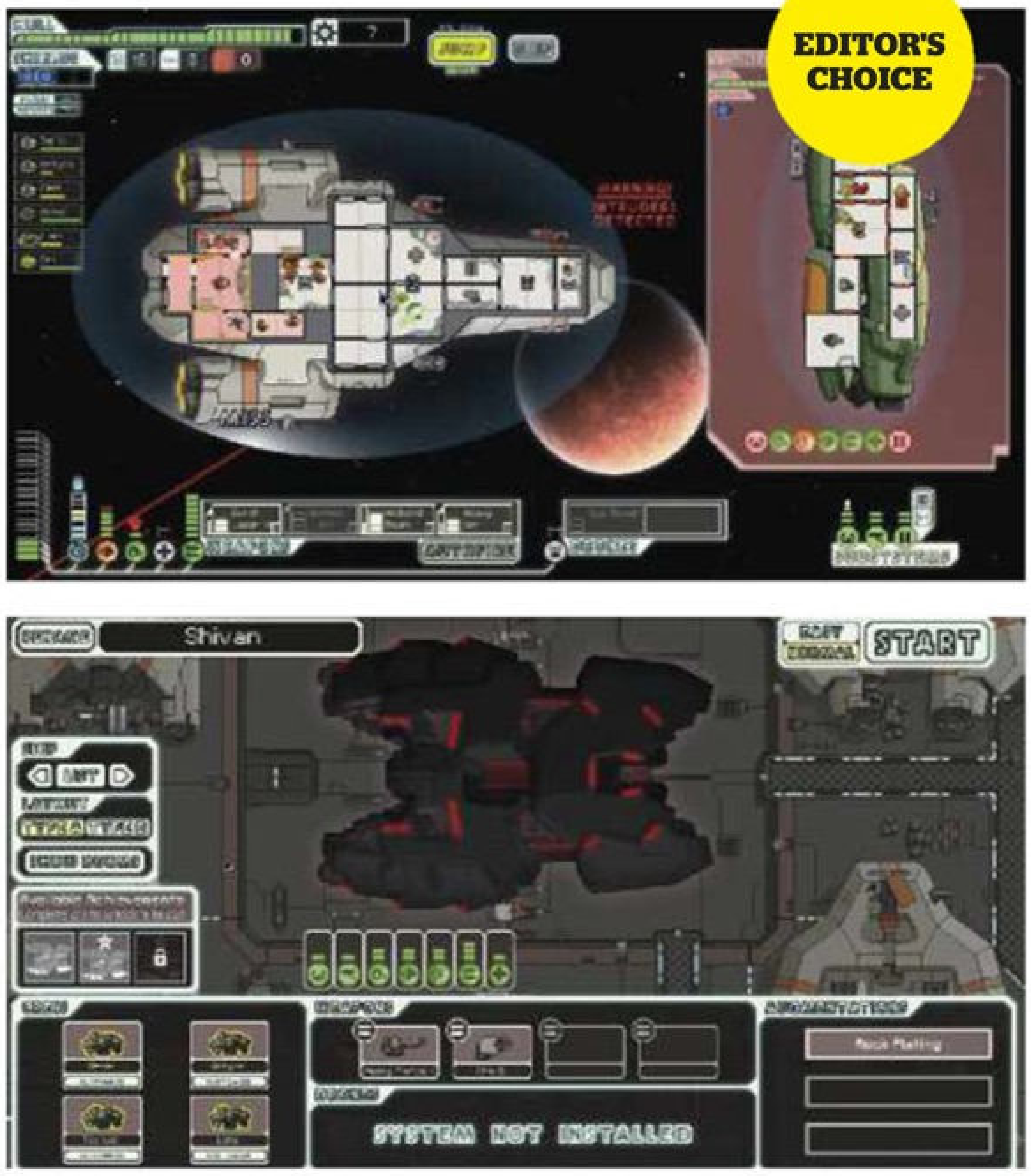
LittleBigPlanet

PS Vita; £34.99

SONY'S CREATIVE PLATFORM game has finally made the leap to the PlayStation Vita. As usual, the key draw here is the ability to craft your own levels, and here the Vita's touchscreens lend a tactile dimension to your architectural efforts. The most important new feature is 'The Memorizer', which lets you explore your latest masterpiece as you're building it. In theory it should allow for epic, complex levels. But if you're pushed for time, just download someone else's hard work.

NEON KELLY is deputy editor at Videogamer.com

EDITOR'S CHOICE



The role of a starship captain involves a lot more than posing in a cool leather chair

FTL: Faster Than Light

PC; £7.99

MOST OF US have flown a starship at some point in our gaming careers, but rarely are we allowed to feel like a bona fide Captain Kirk. *FTL: Faster Than Light* puts you in charge of a humble four-man ship, desperately fleeing an armada of enemy craft. Alone and outgunned, you must flee across the Galaxy and warn your allies of the approaching threat. So far, so familiar – but here's the twist: *FTL* tests your leadership skills, rather than your itchy trigger finger.

Each game starts with you picking your vessel and crew, renaming both as you see fit; if you fancy a ship manned by your nearest and dearest, that's certainly an option. Once you set out into the wide blue yonder (well, the wide *black* yonder) you'll find there's work to be done. There's a constant need to manage the energy levels of your ship, boosting your shields by re-routing the power from your engines, perhaps, or juicing up your lasers for a desperate, all-or-nothing attack. Not every encounter is hostile, but it pays dividends to be on your guard: pirates, aliens and robot sentries lurk in the nebulae – danger is never far away.

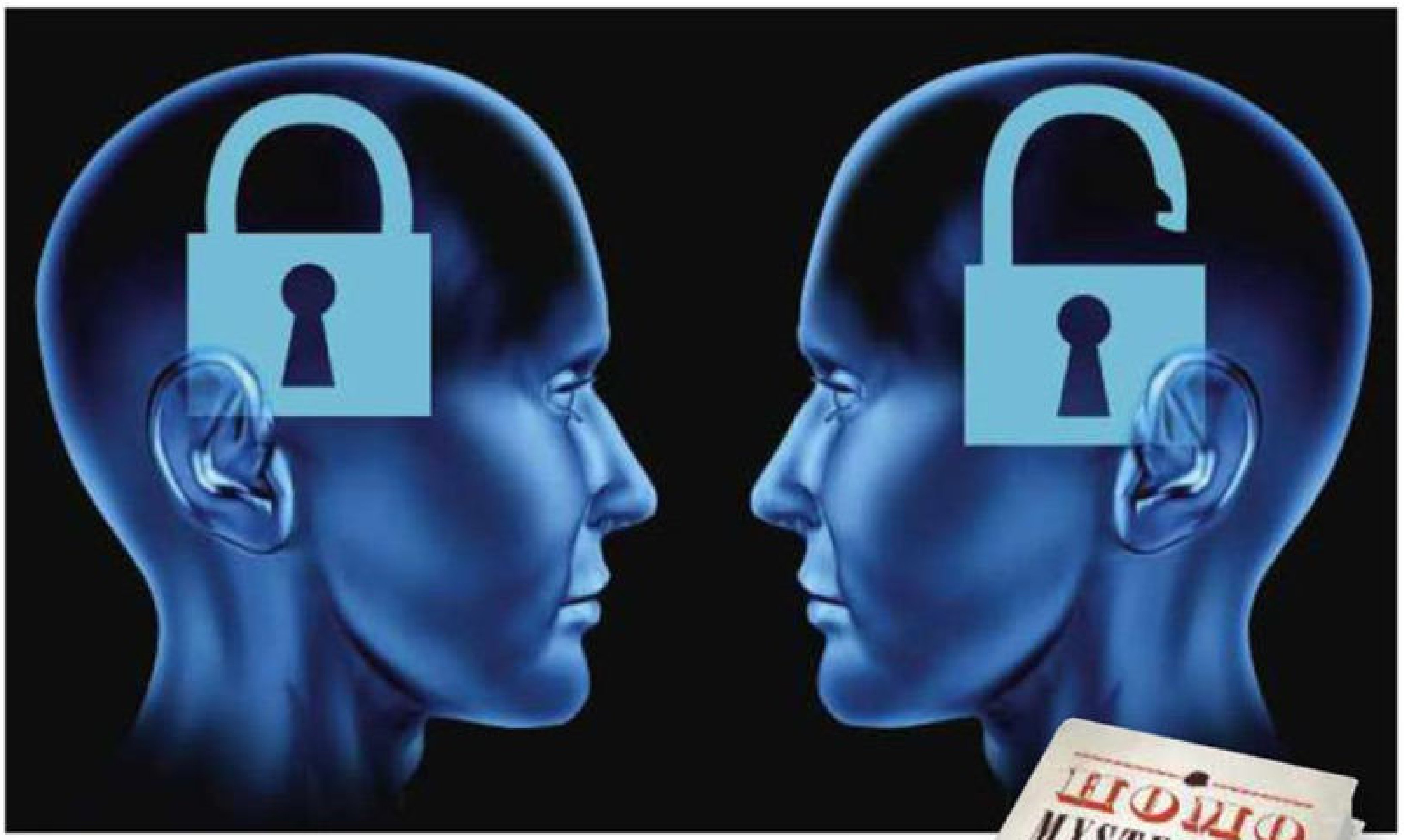
Unlike most sci-fi outings, your ship feels like a living, breathing place, with your team scurrying about to fix things when you fall under attack. On-board fires are a frequent problem, but clever captains will use the vacuum of space to their advantage – venting the room to starve the flames of oxygen. Just try to remember that your crew still need to breathe.

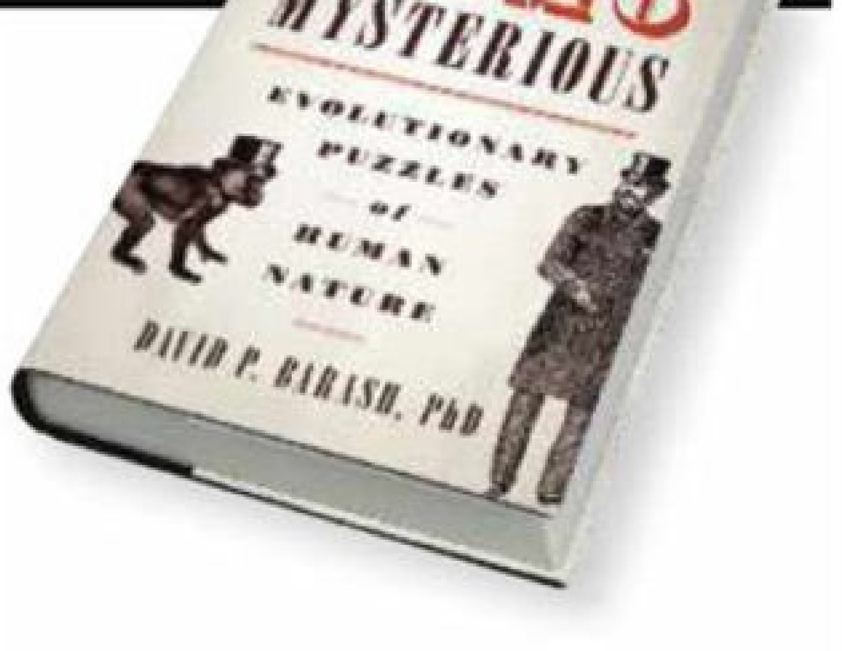
FTL: Faster Than Light lets you star in your own personal episode of *Star Trek* or *Firefly*, and because the world is randomly generated, you'll get a different adventure every time you play. But the most remarkable thing of all? This cracking little game was initially the work of just two people, proving once again that good things really do come in small packages.

READ

THE LATEST SCIENCE BOOKS REVIEWED

P Paperback H Hardback




Homo
Mysterious
Evolutionary Puzzles of Human Nature
David P. Barash, PhD

Homo Mysterious

Evolutionary Puzzles Of Human Nature

David Barash
OUP H £18.99

PEOPLE ARE STRANGE creatures; sometimes we send mixed signals. We claim to value altruism, but tend to scratch backs only when ours have a good chance of being scratched in return. And sometimes we send no signals at all. Unlike many of our primate relatives, human females give no visible – or at least smellable – sign of ovulation. In evolutionary terms, there's nothing a male could want more than to fertilise an egg. So why the big mystery?

In *Homo Mysterious*, David Barash probes evolutionary puzzles such as these, applying the logic of natural selection to human behaviours and the anatomical quirks that enable them. An evolutionary psychologist who's used to feeling the pulse of human minds, Barash begins and ends on a theme of discovery: "Dare to know what we do not know." The lack of clear answers may not satisfy the literal-minded, but Barash entertainingly pursues questions about why and how brains and bodies are built.

A third of the book is about sex, including 12 pages that grapple with questions on breasts (have bigger breasts evolved to communicate fertility, or do they make it more difficult to tell that left and right breasts are different sizes?) There are also two chapters on religion, two on art. In each, Barash ably illustrates how the evolutionary perspective can't always be applied to everything in life.

Sceptical readers might begin to notice that evolutionary psychologists have a way of making things more mysterious than they are. Some scientists may have trouble understanding the point of female orgasms, for instance, but I'd count them as a minority among consenting adults. And do we really need a chimpanzee version of Psalm 23, 'The alpha male is my shepherd'?

The happy side of this absurdity is that Barash's light touch doesn't take his subject overly seriously. Studying evolution is among the most joyful of sciences, opening a window on morally shuttered topics such as sexuality or religion. More scientists should dare to know what we do not know.

■■■■□

DR JOHN HAWKS is a palaeoanthropologist and blogs about evolution at *johnhawks.net*

MEET THE AUTHOR

David Barash

Why did you write this book?
There's a misunderstanding on the part of many people that science is essentially a list of things we already know, whereas there is so much we don't know. This book examines problems of human nature that evolutionary biologists haven't yet answered. I've been doing science for almost 40 years and I've been aware that, in some sense, what my colleagues and I do is a deception: we give the impression that all the big questions have been answered. This book is an effort to try to correct a benevolent misrepresentation on the part of scientists in the way we communicate, particularly to non-scientists.

What surprised you most?
Although scientists are open-minded, I was a little surprised at the extent to which individual scientists find themselves committed to their particular interpretation – their hypothesis. From an objective distance, it's often difficult to decide which one is right. So when palaeoanthropologists discover a fossil, in almost every case they're convinced theirs is the one that sits in the immediate lineage leading to humans.

Which part of the book was most challenging?
The last chapter, in which I describe the variety of mysteries not explored in the book: homosexuality, human consciousness (not so much *how* we're conscious, but *why*) and interesting sexual mysteries like female orgasm. Encouraging people to take the same delight in mysteries that I do was challenging.

MORE ON THE PODCAST
Listen to a longer interview with David Barash on the podcast at sciencefocus.com/podcasts

PHOTO: DREAMSTIME, JUDITH LIPTON

Pieces Of Light

The New Science Of Memory

Charles Fernyhough
Profile H £14.99

CHARLES FERNYHOUGH IS a man in love with memory – his own memories, his young daughter's, his elderly grandmother's – so making a career as a psychologist who studies memory must have been a no-brainer. *Pieces Of Light* is an almost obsessive trawl through the author's own memory bank that also explores some of the strange quirks of memory we all share.

We know the brain is required for learning, retaining and accessing memory, and research has revealed some of the cellular processes that encode new memories. But the mechanisms that enable us to recall things – from a fourth birthday party to the day of the week – remain elusive. This 'autobiographical memory' provides the narrative of our lives, so losing it through brain damage can be a devastating assault on our personhood.

With elegance and clinical sympathy, Fernyhough tells the stories of patients with various forms of brain damage that result in amnesia. Memory may remain an enigma, but this book is a good, accessible read for anyone interested in their own recollections.

■■■■□

PROF STEVEN ROSE is a neurobiologist and co-author of *Genes, Cells And Brains*

The Stardust Revolution

The New Story Of Our Origin In The Stars

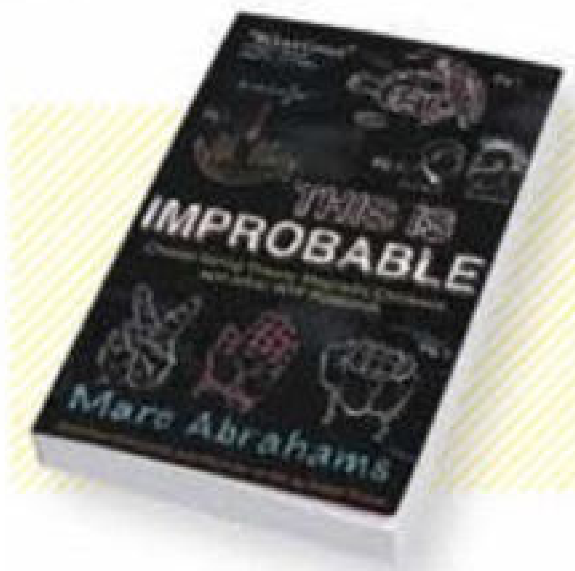
Jacob Berkowitz
Prometheus H £23.95

AN AMBITIOUS ATTEMPT to tackle the emerging story of life's origins on Earth in a cosmic context, this book takes in everything from molecular astrophysics to the discovery of new planets in a clear and breezy style. Science writer Jacob Berkowitz is keen to establish 'the Stardust revolution' – his own term – as being as significant as the Copernican and Darwinian revolutions, so page after page emphasises just how significant everything is. It not only grates, it's also misleading: modern astrochemistry tells us more about star formation than planets, and meteoritics is more about planet formation than life. Berkowitz, however, is obsessed with the origins of life to the exclusion of all else.

Well informed, the book contains few factual errors (although Margaret Burbidge wasn't the first female Astronomer Royal – she was scandalously passed over) but it often fails to identify the real story behind its anecdotes. *The Stardust Revolution* serves best as a pointer to exciting, overlooked research – it just doesn't put that work in its proper context. For that, we may have to wait for a real revolution.

■■□□□

DR CHRIS LINTOTT is an astrophysicist and co-presents *The Sky at Night* on BBC TV



This Is Improbable

Cheese String Theory, Magnetic Chickens, And Other WTF Research

Marc Abrahams
Oneworld P £10.99

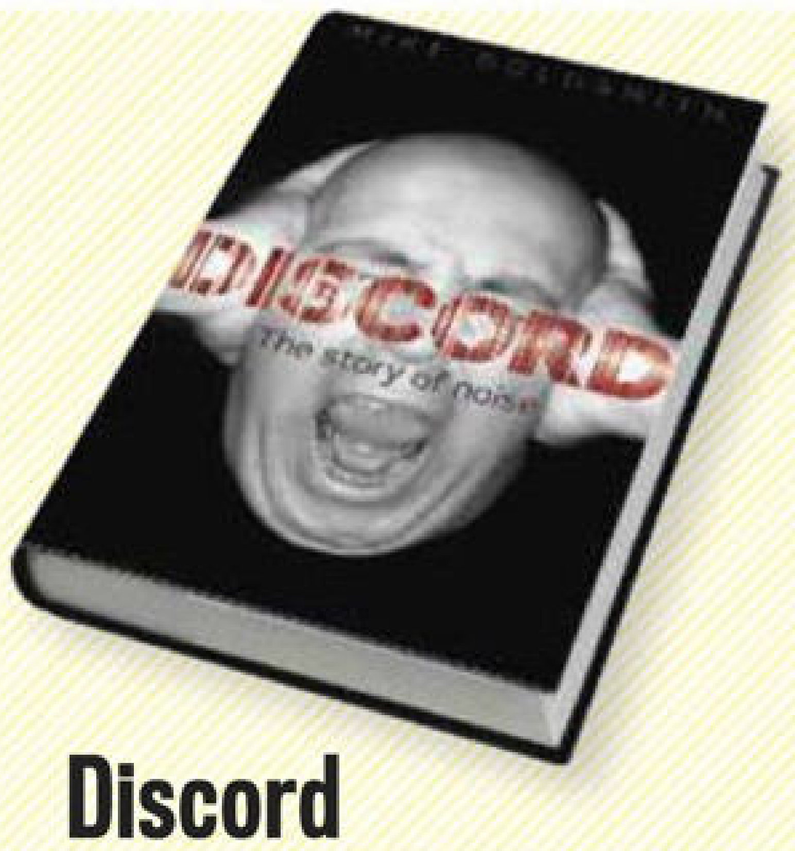
IF YOU'VE EVER wondered what occupies the minds of scientists who aren't looking for that infernal Higgs boson, Marc Abrahams has some examples – at least when it comes to the more off-piste areas of research.

This book is an expansive collection of published papers compiled by Abrahams's Improbable Research organisation, which aims to draw attention to science that will 'first make people laugh, and then make them think'. The organisation is best known for awarding the annual Ig Nobel Prize, which is a little like a regular Nobel Prize, but less earnest. Last year's winners included animal psychologist Dr Anna Wilkinson for her research paper 'No Evidence Of Contagious Yawning In The Red-Footed Tortoise *Geochelone carbonaria*'.

This is Improbable is jam-packed with such examples. Some are funnier than others, but all are fabulously left-field. It's a great reminder that science knows no boundaries, and that the scientific peer-review process doesn't necessarily destroy good humour.

■■■■□

DALLAS CAMPBELL is a presenter of *Bang Goes The Theory* on BBC TV



Discord

The Story Of Noise

Mike Goldsmith
OUP H £16.99

GIVEN OUR VIEW of noise as a 'pollution', it might seem strange to write about what physicist GWC Kaye called 'sound out of place'. National Physical Laboratory acoustics expert Mike Goldsmith, however, provides a fascinating new view.

Goldsmith's writing brings the sounds of past ages vividly to life. Hunter-gatherers avoided camping near running water – which would have masked the sound of approaching enemies and predators – and the inner surfaces of Stonehenge were made smooth and concave to reflect chants. The science of acoustics runs in parallel to this history, and here Goldsmith's expert knowledge comes to the fore. He busts the wiki-myth that the decibel was named after Alexander Graham Bell (the real origin is geekily esoteric), but in maintaining that an unaided human voice cannot shatter a wineglass, he reveals a deaf spot for the *Mythbusters*' successful demonstration.

Presenting medical, military and even cosmological applications, Goldsmith's insight makes for an enjoyable read.

■■■■■

DR MARK LEWNEY is a 'guitar physicist' and a former winner of FameLab

BBC FOCUS

SCIENCE AND TECHNOLOGY

NOVEMBER ISSUE

REDISCOVERING THE LOST WORLD

UNLOCKING THE SECRETS OF A HIDDEN LAND OF MAMMOTH REMAINS, STONE MONUMENTS AND ANCIENT BURIAL SITES

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Entrants must be UK residents (inc Channel Islands) aged 18 or over. Immediate Media employees are not eligible to enter. By entering participants agree to be bound by these terms and conditions and that their name and county may be released if they win. Only one entry permitted per person. No responsibility is accepted for lost, delayed, ineligible or fraudulent entries. The closing date and time are as shown on page 120. Entries received after that will not be considered. Entrants must supply their full name, address and daytime phone number. Immediate Media (publisher of Focus magazine) will only ever use personal details for the purposes of administering this competition unless you permit otherwise. Read more about the Immediate Privacy Policy at www.immediatemedia.co.uk/privacy-policy. The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown on the Crossword page. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. The name and county of residence of the winners will be published in the magazine within three months of the closing date. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.

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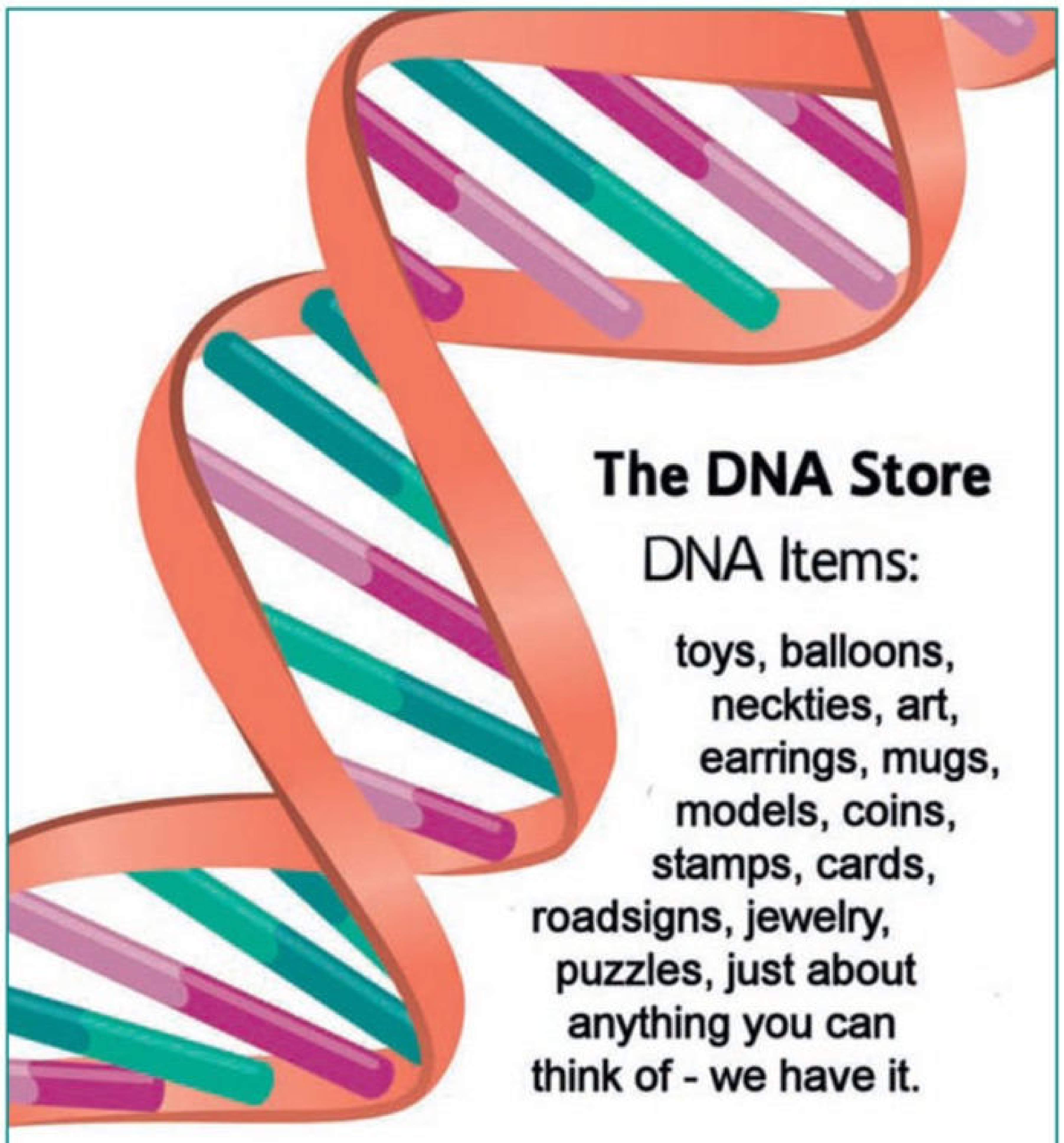

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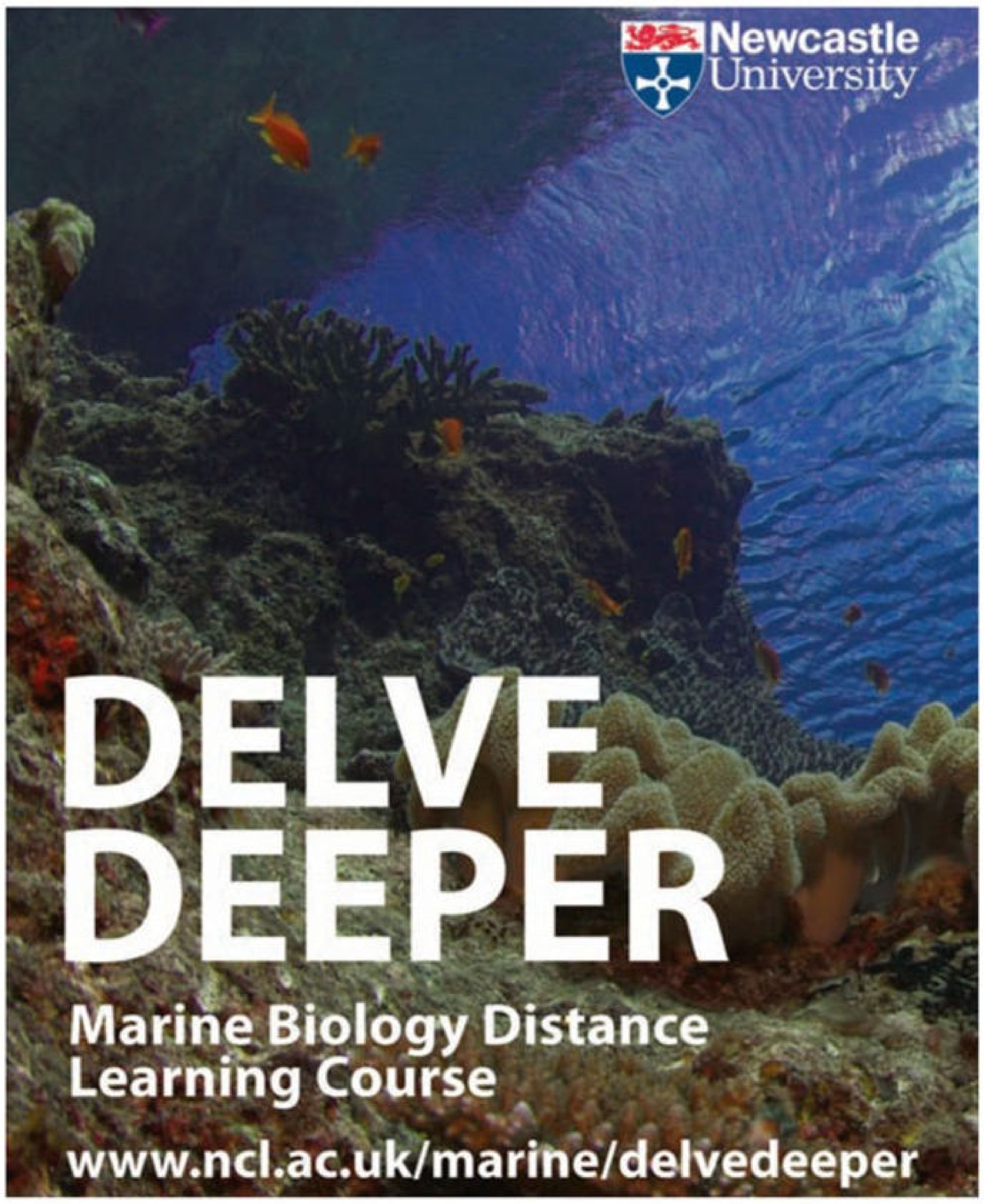

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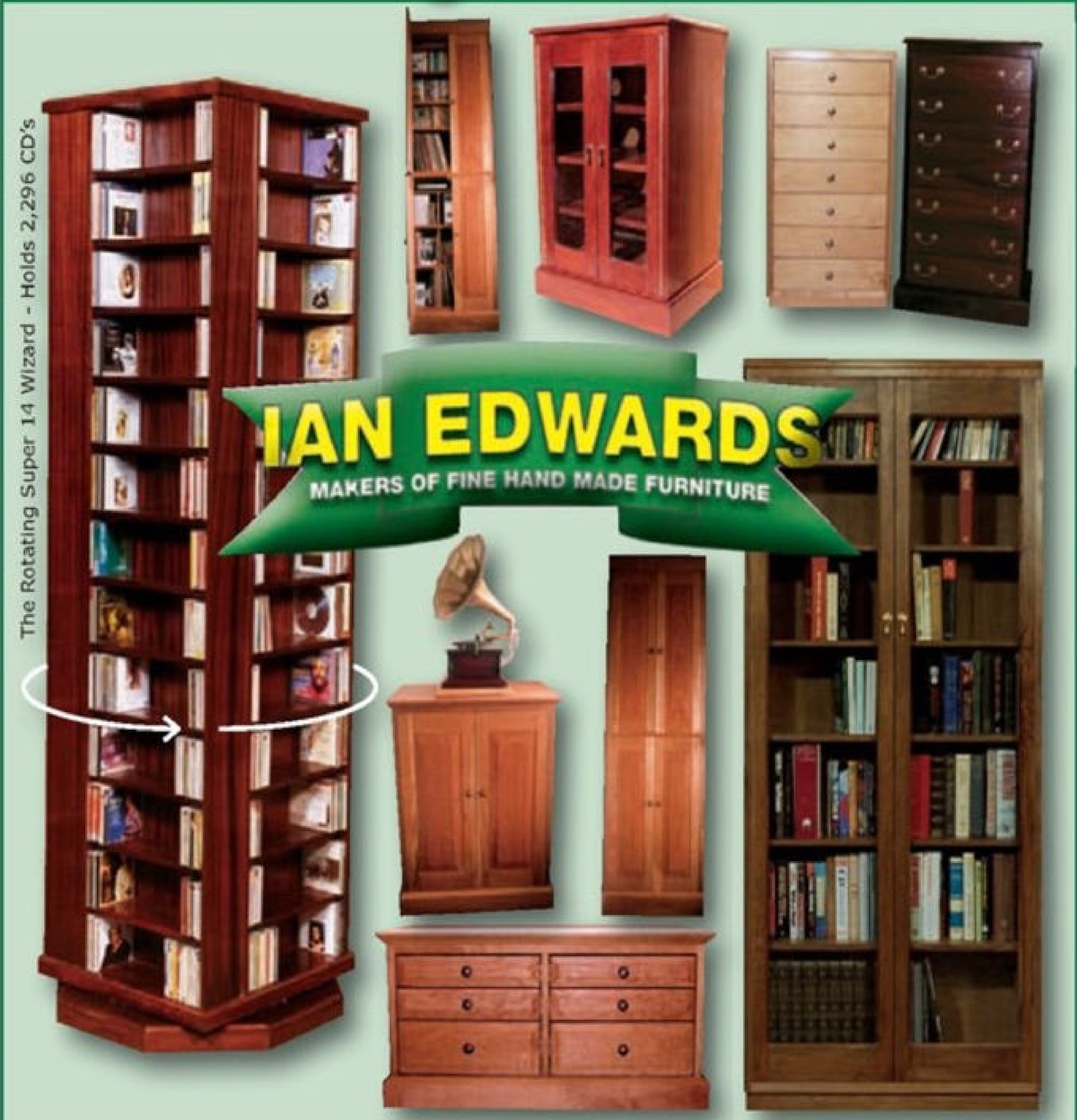

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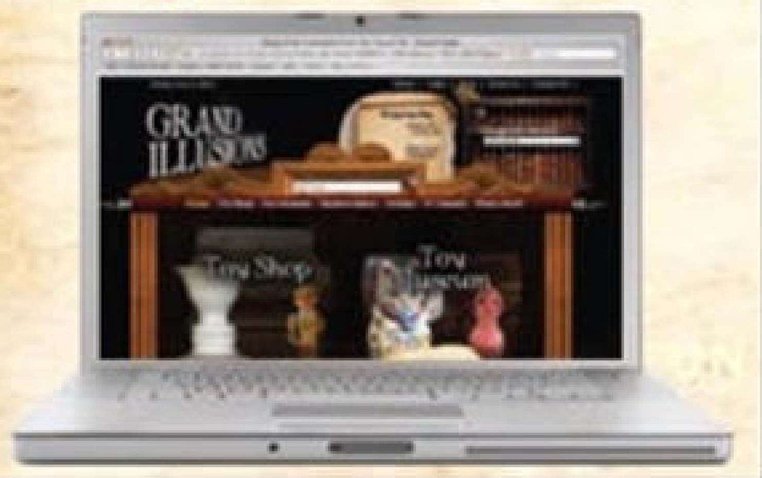

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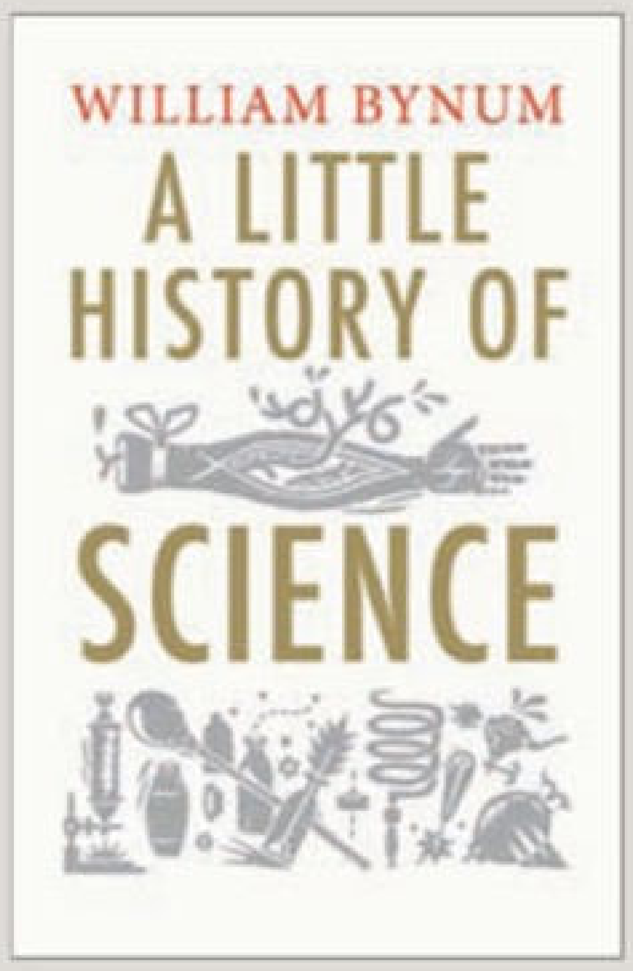

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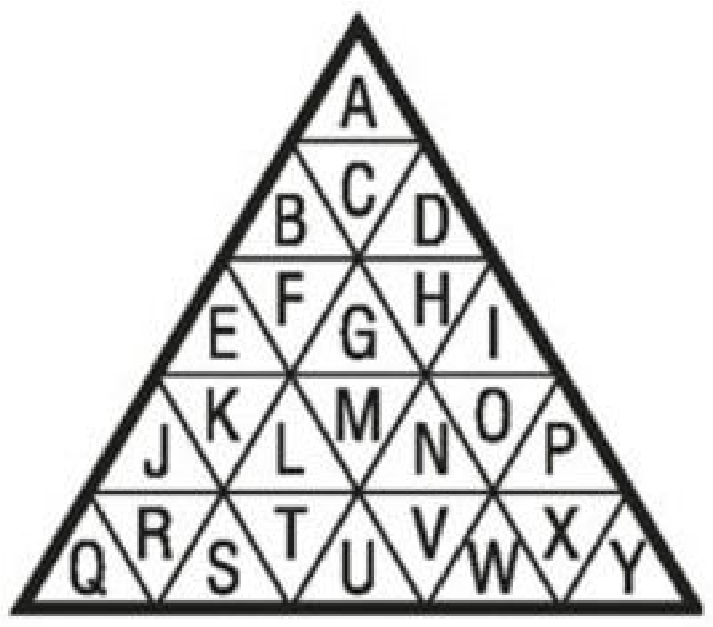
Pit your wits against these brainteasers by David J Bodycombe, question-setter for BBC Four's *Only Connect*

PRIZE PUZZLE

Drawing along the grid lines, what is the smallest number of equilateral triangles that this shape can be divided into?



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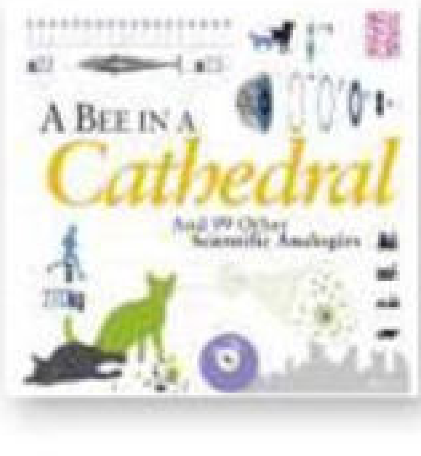
The first five correct entries will win a copy of *A Bee In A Cathedral* (Bloomsbury, £12.99).

Post your entry, marked 'Prize Puzzle 247', to: *Focus* magazine, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 18 October 2012. We regret that we cannot accept email entries for this competition.



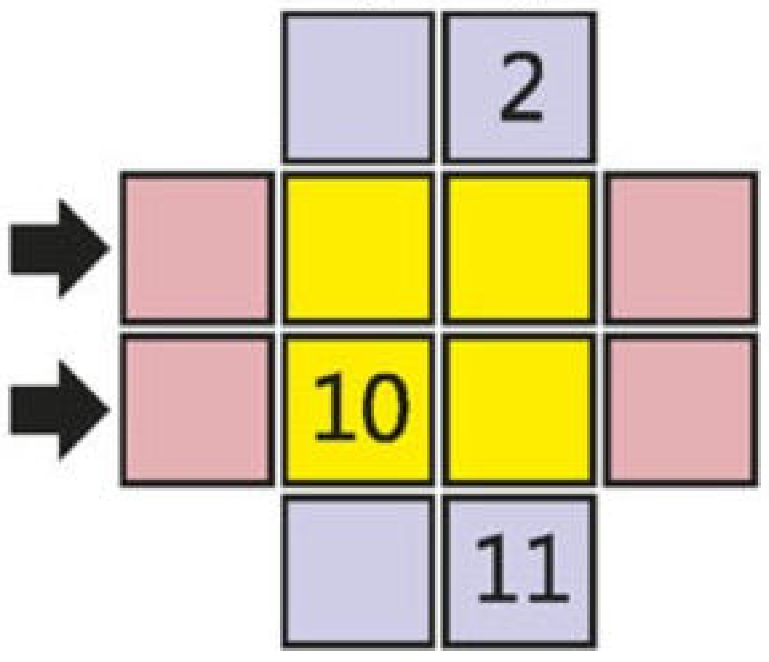
See bottom of p112 for terms and conditions. Congratulations to John Rouse (Leicestershire), Karen Boyne (Renfrewshire) and Luke Lawson-McLean (Edinburgh), who all answered the Summer issue's Prize Puzzle correctly to each win a copy of *I Didn't Know That Vol 2* on DVD.

Q1

How is it possible for your father to be older than your grandfather?

Q2

Place the remaining numbers from 1 to 12 so that the two rows, two columns and the three different coloured sets of four squares all total 26 each.

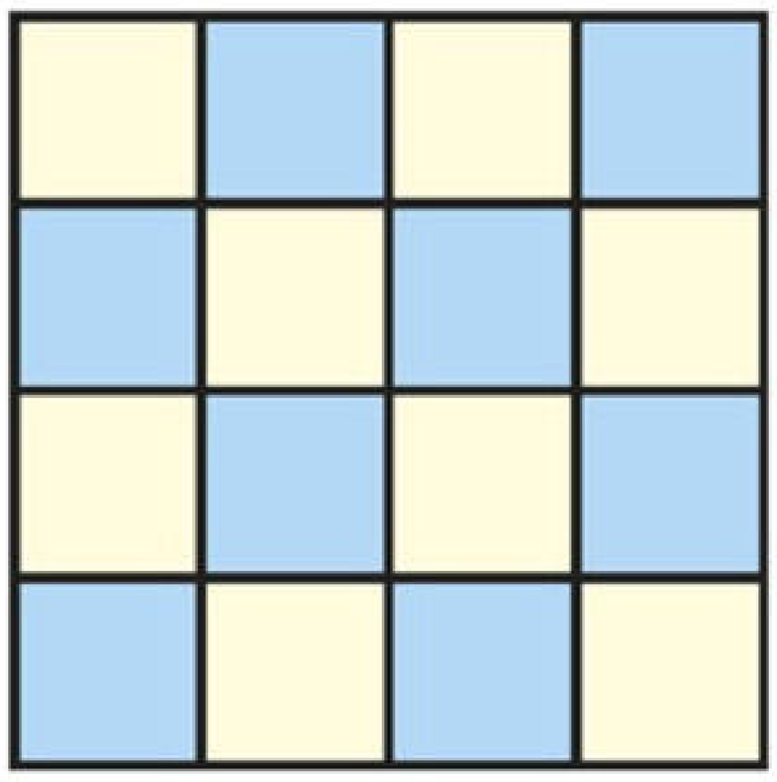


Q3

The O, S, T and Z are only capable of clearing singles and doubles. The L and J can also clear triples, but only the I can clear a quadruple. What are we describing?

Q4

How many chess knights are required below so that every square contains, or is attacked by, a knight?



Q5

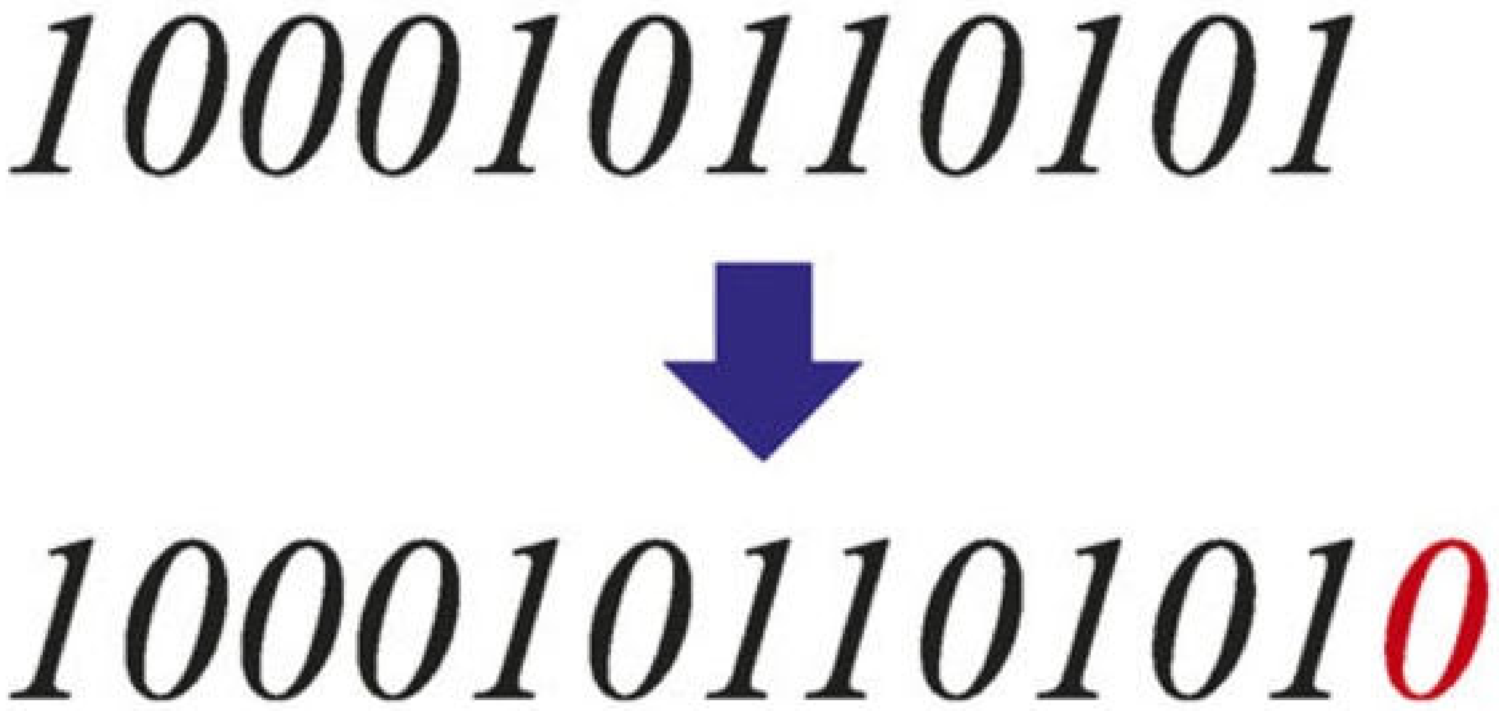
Which two-digit number, multiplied by itself five times, is 8,587,340,257? (Hint: first, find a way to deduce the second digit.)

Q6

Although the calculation 1/3 = 1/4 + 1/5 is incorrect, is it possible to pick three numbers that are one apart (instead of 3, 4 and 5) so that it works?

Q7

Suppose you take any binary number and add a '0' to the right-hand end. Precisely how has that affected the value?



Q8

Draw 2x1 rectangles around pairs of numbers so that when complete, the diagram contains a full set of 28 dominoes from double 0 to double 6.

2	3	3	3	5	6	6	1
4	3	5	6	4	1	1	4
0	5	0	6	0	5	2	4
1	5	3	5	0	4	4	1
4	3	1	5	3	6	6	0
1	2	2	2	4	3	5	1
6	2	2	0	2	6	0	0

SOLUTIONS

Q1) Although your father's father cannot be younger than your father, your mother's father could be if your father married a much younger woman.

Q2) Top row: 5, 2; second row: 4, 3, 7, 12; third row: 1, 10, 6, 9; bottom row: 8, 11. Other solutions exist.

Q3) The pieces (tetrominoes) made up of four joined squares that are used in the computer game *Tetris*. Each piece is given a nickname based on the letter it most closely resembles.

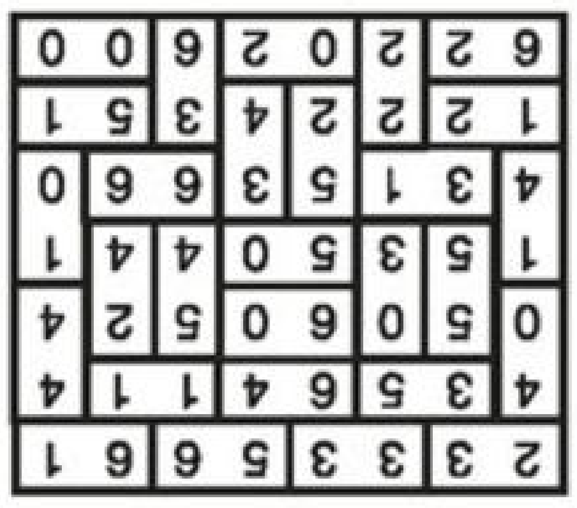
Q4) Four, occupying the centre spaces.

Q5) Whenever you raise a number, X, to the fifth power, the final digit of the result is the same as the second digit of X. Because the result is close to 10 billion (100^5), X must be 97.

Q6) Write as: $1/x = 1/(x+1) + 1/(x+2)$ which can be rewritten $(x+1)(x+2) = x((x+2)+(x+1))$, hence $x^2 + 3x + 2 = 2x^2 + 3x$. The 3x cancels to give $2x^2 = x^2 + 2$, so $x^2 = 2$ or $x = \sqrt{2}$. Hence, the three numbers are $1/(\sqrt{2})$, $1/(\sqrt{2}+1)$ and $1/(\sqrt{2}+2)$.

Q7) The value has been doubled.

Q8) See illustration.



QUICK QUIZ

How much do you know about volcanoes?

Q1

Which term describes the most dangerous type of volcano?

a) Supervolcano
b) Ultravolcano
c) Megavolcano

Q2

There are approximately how many potentially active volcanoes on Earth today?

a) 150
b) 1,500
c) 15,000

Q3

The Ring of Fire borders which ocean?

a) Atlantic
b) Pacific
c) Indian

Q4

When was the most famous eruption of Vesuvius?

a) AD 79
b) AD 779
c) AD 1779

Q5

What term describes lava containing less than 45 per cent silica?

a) Felsic
b) Andesitic
c) Ultramafic

Q6

What is the most volcanically active object in the Solar System?

a) Venus
b) Jupiter's moon Io
c) Saturn's moon Titan

Q7

Mount Etna is located on which Mediterranean island?

a) Sardinia
b) Cyprus
c) Sicily

Answers: 1a, 2b, 3b, 4a, 5c, 6b, 7c

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4-5 Dormant
6-7 Active

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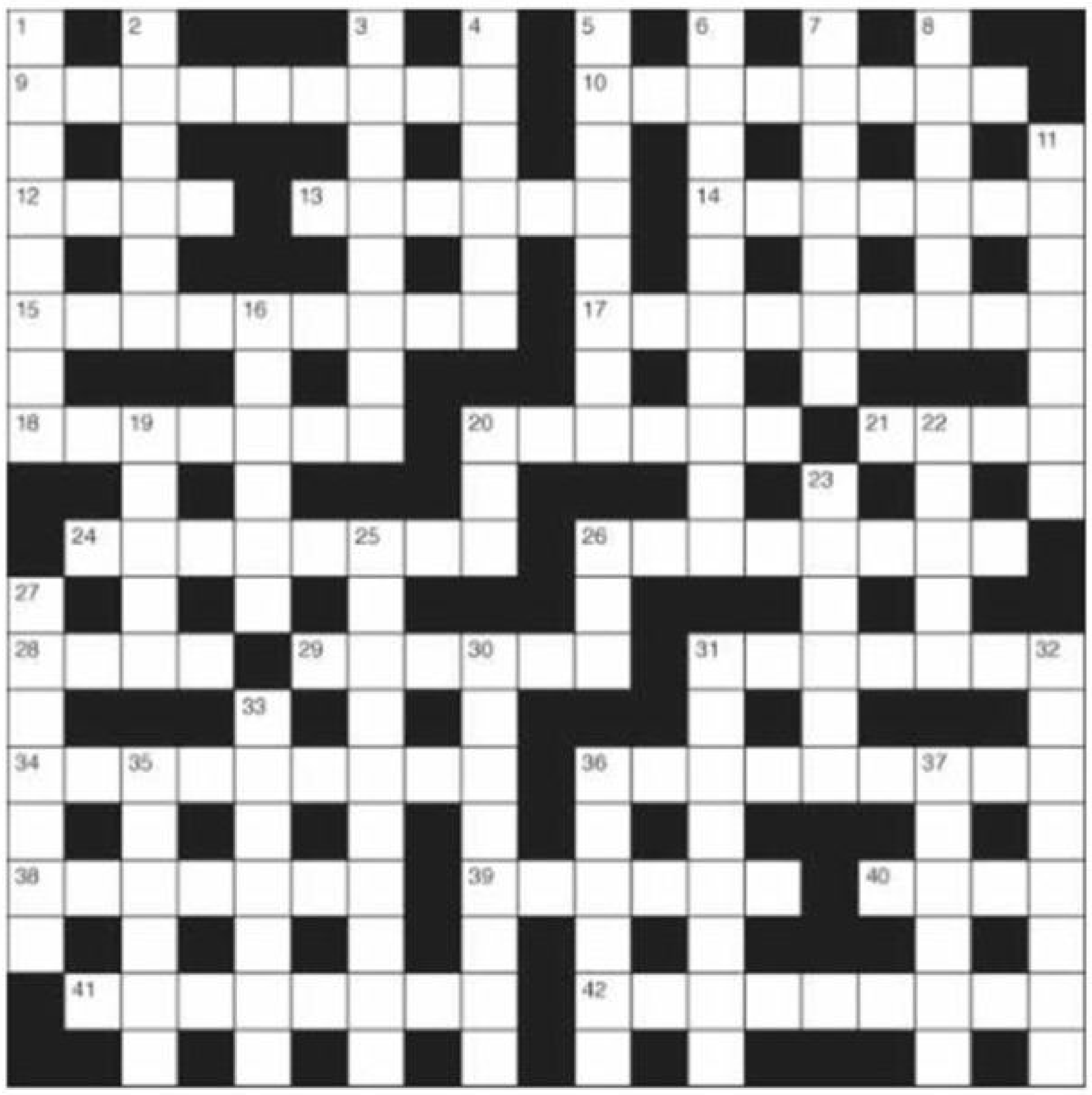


ACROSS

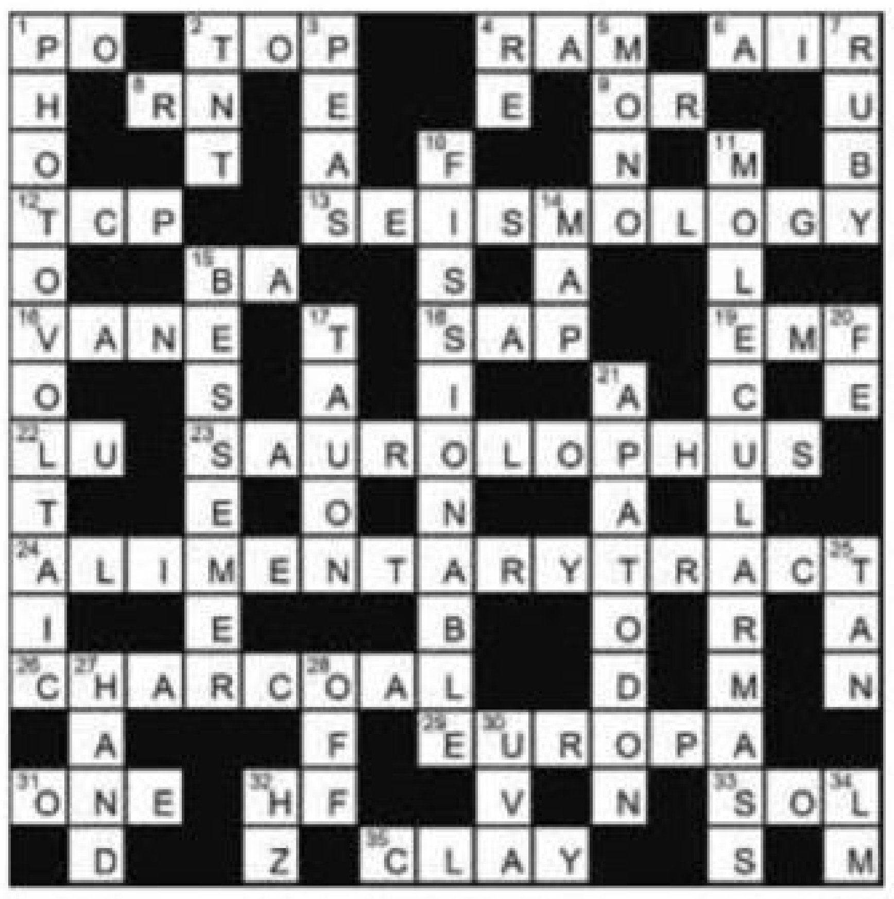
9 Same potty arrangement shows line approaching curve (9)
10 Bad conductor has no mental capability (3-5)
12 The sort to use a machine to write (4)
13 Drip involved in transaction outside (6)
14 Time for some coffee (7)
15 Circus performer may have to get in such shape (9)
17 More tales about flexible substance (9)
18 Wearing best tux reveals hidden message (7)
20 Celebration has one equivalence (6)
21 Most of us have curd (4)
24 Chinese art displaying huge fins (4,4)
26 Firm attack with firm bone (8)
28 Pressure to finish edge of fabric (4)
29 Difficult to get every character in danger (6)
31 A slim form in charge of a religion (7)
34 Coy clue about the hollow blood cell (9)
36 Judge right to give performer a telescope (9)
38 Around old church, field is part of 5 Down (7)
39 Creature has article to mail off (6)
40 Feeble person gets user-friendly display (4)
41 Bad apes ride something which keeps plane off the ground (8)
42 Nordic island – I'd cancel excursion (9)

DOWN

1 Supporter finds it's an inflammation (8)
2 Cleaner takes year to find one with a visual impairment (6)
3 Boat isn't used by plant expert (8)
4 Sing about fellow having gas (6)
5 Pub has point to bring up within hearing (5,3)
6 A mint treat composed of opposite substance (10)
7 God takes Poles to Mass (7)
8 Sodium lamp turned into a weapon (6)
11 Whole bird included breastbone (7)
16 Terribly green, variable source of power (6)
19 Swimmer turned amber (5
20 Graphic about Greek character (3)
22 Analgesic starts to operate properly in under minute (5)
23 Calls round about unknown sea monster (6)
25 Serious drink that's deuterium-enriched (5,5)
26 Copper gets daughter some food that's not fresh (3)
27 Shakespearean character disinclined to get close (7)
30 Lead new attendant to city (8)
31 During RAF manoeuvre, socialist makes long waves (8)
32 Shell to transport quickly (8)
33 Doctor culls form of snail, say (7)
35 Roguish child who gets spiny in the sea (6)
36 Endlessly bringing up fruit (6)
37 Tried working with old valve (6)

SOLUTION TO SCIENCE No 3

Ron Bridges, Steve Cooper, Peter Haworth, Linda Cannard and Diana Sanders solved the issue 244 puzzle and each receive a copy of *The Universe Inside You* by Brian Clegg.



P	O	■	T	O	P	■	■	R	A	M	■	A	I	R
H	■	R	N	■	E	■	■	E	■	O	R	■	■	U
O	■	■	T	■	A	■	F	■	■	N	■	M	■	B
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O	■	■	B	A	■	■	S	■	A	■	■	L	■	■
V	A	N	E	■	T	■	S	A	P	■	■	E	M	F
O	■	■	S	■	A	■	I	■	■	A	■	C	■	E
L	U	■	S	A	U	R	O	L	O	P	H	U	S	■
T	■	■	E	■	O	■	N	■	■	A	■	L	■	■
A	L	I	M	E	N	T	A	R	Y	T	R	A	C	T
I	■	■	E	■	■	■	B	■	■	O	■	R	■	A
C	H	A	R	C	O	A	L	■	■	D	■	M	■	N
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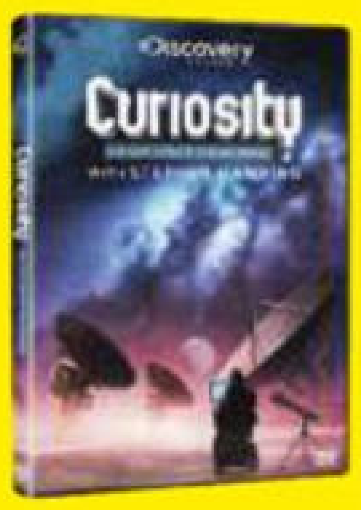
WIN! A COPY OF *CURIOSITY – DID GOD CREATE THE UNIVERSE?* WITH STEPHEN HAWKING

The first five correct solutions drawn will each win a copy of *Curiosity – Did God Create The Universe? With Stephen Hawking* (Discovery Channel; £12.99). Entries must be received by 5pm on 18 October 2012. See below for more details.



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Post entries to *Focus*, October 2012 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to october2012@focuscomps.co.uk by 5pm on 18 October 2012. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 112. Immediate Media, publisher of *Focus*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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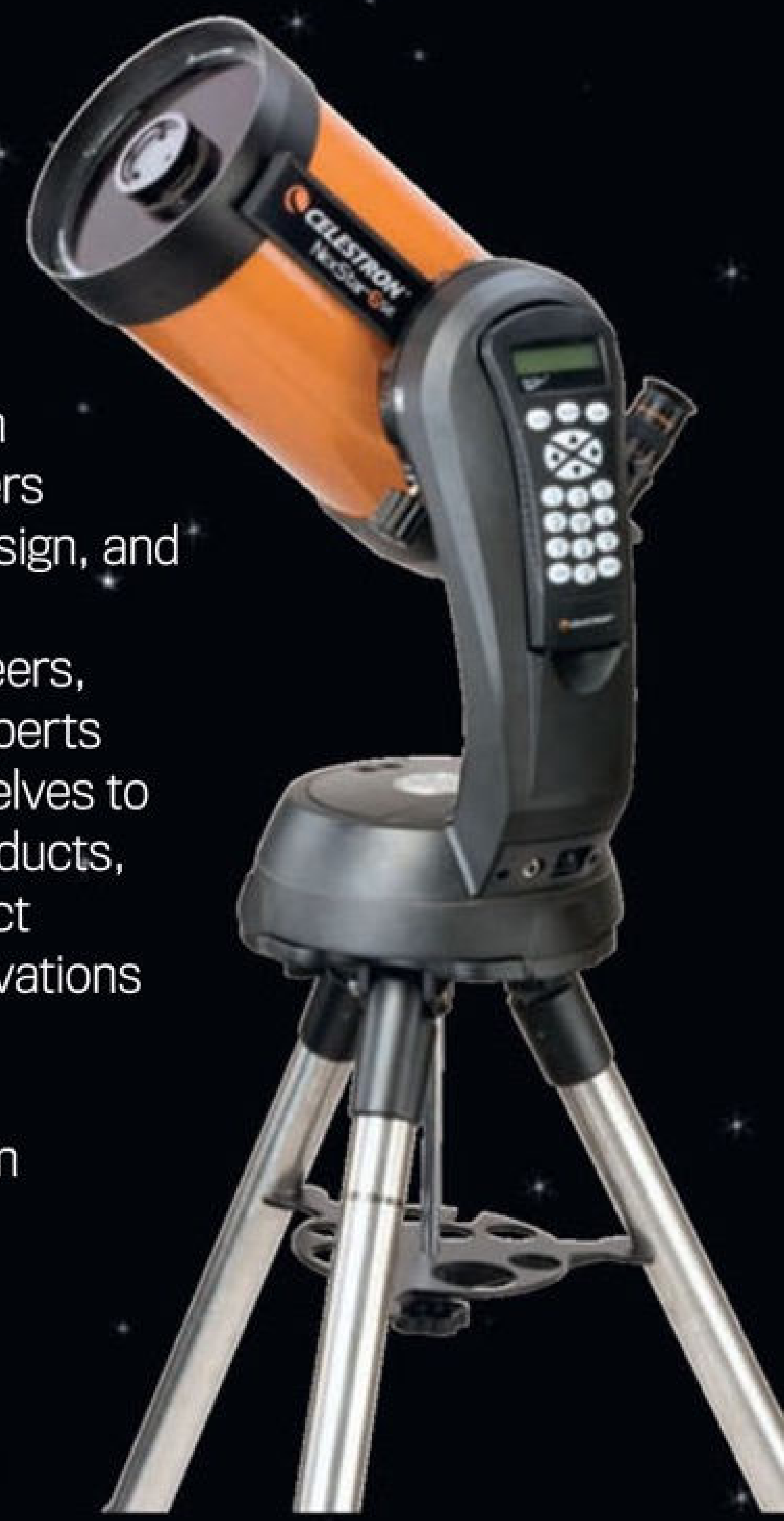

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INTO THE FUTURE

STEPHEN BAXTER

THE SPRING OF 2012 brought the alarming news of a gas leak on a North Sea drilling platform, operated by the French oil and gas group Total, about 140 miles east of Aberdeen. Perhaps many of us in Britain take for granted our North Sea oil and gas industry, until something goes wrong. But once, mining the North Sea represented a grand technological challenge.

Will mankind soon be plundering Martian resources?

It even featured in *Doctor Who*! In the story 'Fury From The Deep', broadcast in March-April 1968, the setting is a futuristic complex of rigs and refineries on the east English coast. Unfortunately a sentient, mind-controlling seaweed, disturbed by the drilling, tries to invade the land. Perhaps the weed can be seen as a metaphor for an over-exploited environment striking back.

In the real world, exploratory drilling in the North Sea struck gas in 1965, and oil in 1969. Commercial production began in June 1975, when Tony Benn, then Energy Secretary, made his way to the Medway estuary in Kent, to be photographed with a flask of the first oil to be delivered to a UK mainland refinery.

Huge wealth was generated, and an independent fuel supply was recognised as being of strategic importance to the UK economy. But from the beginning this was always a hazardous enterprise because of the ferocious weather conditions, and there have always been concerns about the ecological and environmental impact of the drilling.

Today, though still a vast industry, North Sea oil and gas production is declining; the UK is now a net importer of oil again. What next for the drillers?

The next great challenge could well be the Arctic Ocean, where global temperature rises have melted the ice cover in a region where perhaps a quarter of the world's remaining hydrocarbon reserves may reside. Even compared to the North Sea, work here will be extraordinarily difficult because of the cold temperatures and rough seas, and probably not even possible during the dark winter months. But it's thought that the region could see investment of $100 billion over the next decade, with projects planned off the northern coasts of Canada, Greenland and Russia. Insurance companies like Lloyd's of London are already flagging concerns about impacts on the region's fragile ecologies, not least from oil spills.

> **"A significant challenge would be to drill down a kilometre through the Martian rock, to where deep aquifers are thought to lie"**

Even greater challenges may await the roughnecks of the future, such as drilling on Mars. As I noted in my column in *Focus* issue 233 (September 2011, p78), we might try to extract ice cores from Mars's polar caps to retrieve climate records, just as we do on Earth. A useful core might need to be 100m deep, perhaps. But a much more significant challenge would be to drill down a kilometre or more through the Martian rock, to where deep aquifers, beds full of water, are thought to lie.

Martian deep drilling has been studied by visionary groups such as the Mars Society. In a paper published in the *Proceedings of the Founding Convention of the Mars Society* edited by Robert Zubrin (San Diego, 1998), one group gave a detailed design of a drill rig built into a dedicated spacecraft.

Any large industrial operation will be a challenge on Mars. In the dusty, cold Martian environment, any moving-part mechanical system will be vulnerable to failure modes we're not familiar with on Earth – lubrication faults, the abrasion of bearings, metal fatigue in the cold. Again, there could be ecological concerns, if there are any native life forms in the Martian ground. But the prize would be an invaluable one, for, if we can reach them, the vast reserves of primordial water locked up in the aquifers may eventually sustain a permanent human presence on the Red Planet. ■

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